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Annual Progress Report

North Central Regional Aquaculture Center

Annual Progress Report

Disciplines
Agriculture | Aquaculture and Fisheries

NORTH CENTRAL
REGIONAL AQUACULTURE CENTER

ANNUAL PROGRESS REPORT

January 1996

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For the Period
September 1, 1994 to August 31, 1995

January 1996

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INTRODUCTION

The U.S. aquaculture industry continues to be one of the fastest growing sectors within U.S. agriculture, although at a lesser rate than what occurred during the 1980s. Production in 1990 reached 861 million pounds and generated approximately $762 million for producers. The impact of U.S. aquaculture in 1990 was substantial: final sales value totalled $4.75 billion; direct and indirect economic impact was estimated to be $8.0 billion. Yet, anticipated growth in the industry, both in magnitude and in species diversity, continues to fall short of expectations.

Much of what is known about aquaculture science is a result of institutional attention given to our traditional capture of wild fisheries with the goal of releasing cultured fishes into public waters for enhancement of declining public stocks. Despite extensive efforts to manage wild populations for a sustained yield, as a nation we consume substantially greater amounts than we produce. Much of the United States' demand for seafood has been met by imports. The U.S. imports over 40% of its fish and shellfish and, after Japan, is the world's second largest importer of seafood. Fisheries imports---some $10.6 billion per year---are the largest contributor to the U.S. trade deficit among agricultural products, and third largest overall after petroleum and autos. The value of imported fisheries products more than doubled during the 1980s. In 1993, the trade deficit was $3.7 billion for all fisheries products, $2.8 billion of which was for edible fish and shellfish. In fact, foreign-grown aquaculture products constitute some $800 million of our fisheries imports.

Landings for most commercial capture fisheries species and recreational fisheries of the United States have been relatively stable during the last decade, with many fish stocks being overexploited. In this situation, aquaculture provides an opportunity to reduce the trade deficit and meet the rising U.S. demand for fish products. A strong domestic aquaculture industry is needed to increase U.S. production of fish and shellfish. This can be achieved by a partnership among the Federal Government, State and local public institutions, and the private sector with expertise in aquaculture development.

Congress recognized the opportunity for making significant progress in aquaculture development in 1980 by passage of the National Aquaculture Act (P.L. 96-362). Congress amended the National Agricultural Research, Extension, and Teaching Policy Act of 1977 (P.L. 95-113) in Title XIV of the Agriculture and Food Act of 1981 (P.L. 97-98) by granting authority to establish aquaculture research, development, and demonstration centers in the United States in association with colleges and universities, State Departments of Agriculture, Federal facilities, and non-profit private research institutions. Five such centers have been established: one in each of the northeastern, north central, southern, western, and tropical/subtropical Pacific regions of the country. The 1990 Farm Bill (Food, Agriculture Conservation, and Trade Act of 1990 - P.L. 101-624) has reauthorized the Regional Aquaculture Center program at $7.5 million per annum. As used here, a center refers to an administrative center. Centers do not provide monies for brick-and-mortar development. Centers encourage cooperative and collaborative aquaculture research and extension educational programs that have regional or national application. Center programs complement and strengthen other existing research and extension educational programs provided by the U.S.

Department of Agriculture (USDA) and other public institutions. As a matter of policy, centers implement their programs by using institutional mechanisms and linkages that are in place in the public and private sector.

The mission of the Regional Aquaculture Centers (RACs) is to support aquaculture research, development, demonstration, and extension education to enhance viable and profitable U.S. aquaculture production which will benefit consumers, producers, service industries, and the American economy.

The North Central Regional Aquaculture Center (NCRAC) was established in February 1988. It serves as a focal point to assess needs, establish priorities, and implement research and extension educational programs in the twelve state agricultural heartland of the United States which includes Illinois, Indiana, Iowa, Kansas, Michigan, Missouri, Minnesota, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin. NCRAC also provides coordination of interregional and national programs through the National Coordinating Council for Aquaculture (NCC). The council is composed of the RAC directors and USDA aquaculture personnel.

ORGANIZATIONAL STRUCTURE

Michigan State University (MSU) and Iowa State University (ISU) work together to develop and administer programs of NCRAC through a memorandum of understanding. MSU is the prime contractor for the Center and has administrative responsibilities for its operation. The Director of NCRAC is located at MSU. ISU shares in leadership of the Center through an office of the Associate Director who is responsible for all aspects of the Center's publications, technology transfer and outreach activities.

At the present time the staff of NCRAC at MSU includes Ted R. Batterson, Director and Liz Bartels, Executive Secretary. The Center Director has the following responsibilities:

- Serving as executive secretary to the Board of Directors, responsible for preparing agenda and minutes of Board meetings;
- Serving as an ex-officio (non-voting) member of the Technical Committee and Industry Advisory Council;
- Coordinating the development of research and extension plans, budgets, and proposals;
- Coordinating and facilitating interactions among the Administrative Center, Board of Directors, Industry Advisory Council, and Technical Committee;
- Monitoring research and extension activities;
- Arranging for review of proposals for technical and scientific merit, feasibility, and applicability to priority problems and preparing summary budgets and reports as required;
- Recruiting other Administrative Center staff as authorized by the Board of Directors;
- With assistance of the Economics and Marketing Work Group, Technical Committee, or others preparing a summary of regional aquaculture, including production statistics and sales, and identifying technical, financial, and institutional constraints to expanding production. The summary shall include sections addressing established industries, development industries, and opportunities for new product development, and recommended research needs;

- Maintaining liaison with other RACs; and
- Serving on the NCC.

At the present time the staff of NCRAC's Office for Publications and Extension Administration at ISU includes Joseph E. Morris, Associate Director and Glenda Dike, Secretary. The Associate Director has the following responsibilities:

- Serving as head of Publications for NCRAC, including editor of the *NCRAC Journal*, the newsletter of the Center;
- Serving as the NCRAC liaison with national aquaculture extension programs, including in particular, extension programs of the other four USDA RACs; and
- Serving as a member of NCRAC's Extension Executive Committee.

The Board of Directors (BOD) is the primary policy-making body of the NCRAC. The BOD has established an Industry Advisory Council (IAC) and Technical Committee (TC). Membership of the BOD consists of two persons from the IAC (the chair and an at-large member), a representative from the region's State Agricultural Experiment Stations and Cooperative Extension Services, a member from a non-land grant university and representatives from the two universities responsible for the center: Michigan State and Iowa State. The IAC is composed of representatives from each state's aquaculture association and six-at-large members appointed by the BOD who represent various sectors of the aquaculture industry and the region as a whole. The TC is composed of a sub-committee for Extension (TC/E) and a subcommittee for Research (TC/R). Directors of the Cooperative Extension Service within the North Central Region appoint representatives to the TC/E. The TC/R has broad regional make-up and is composed of scientists from universities and state agencies with varied aquacultural expertise who are appointed by the BOD. Each sub-committee of the TC has a chairperson who serves as an ex-officio member of the BOD.

NCRAC functions in accordance with its *Operation Manual* which is periodically amended and updated with BOD approval. It is an evolving document that has changed as the Center's history lengthens. It is used for the development of the cooperative regional aquaculture and extension projects that NCRAC funds.

ADMINISTRATIVE OPERATIONS

Since inception of NCRAC February 1, 1988, the role of the Administrative Center has been to provide all necessary support services to the BOD, IAC, TC, and project work groups for the North Central Region as well as representing the region on the NCC. As the scope of the NCRAC programs expand, this has entailed a greater work load and continued need for effective communication among all components of the Center and the aquaculture community.

The Center functions in the following manner.

- After BOD approval of Administrative Center costs, the Center submits a grant to USDA/CSREES/Grants Management Branch for approval. To date the Center has received eight grants from USDA for FY88 (Grant #88-38500-3885), FY89 (Grant #89-38500-4319), FY90 (Grant #90-38500-5008), FY91 (Grant #91-38500-5900), FY92 (Grant #92-38500-6916), FY93 (Grant #93-38500-8392), FY94 (Grant #94-38500-0048), and FY95 (Grant #95-38500-1410) with monies totalling $5,680,501. Currently, five grants are active (FY91-95); the first three grants (FY88-90) have terminated.

- The Center annually coordinates a program planning meeting which sets priorities for the next funding cycle and calls for regional workshops to develop project outlines to address priority problem areas.
- Work Groups, which are formed at the workshops, submit project outlines to the Center. The projects are peer reviewed by experts from both within and outside the region.
- The BOD, using reviewers' responses, decide which projects are to be approved and funding levels. The Center conveys BOD decisions to all Project Work Groups. Those that are approved for funding are asked to submit revised project outlines incorporating BOD and reviewers' comments.
- The Center then submits the revised project outlines as a Plan of Work (POW) to USDA for approval.
- Once a POW is approved by USDA, the Center then prepares subcontracts for each participating institution. The Center receives all invoices for subcontractual agreements and prepares payment vouchers for reimbursement. Thus, the Center staff serve as fiscal agent for both receiving and disbursing of funds in accordance with all terms and provisions of the grants.

To date, the Center has funded or is funding 36 projects through 207 subcontracts from the eight grants received. Funding for all Center supported projects, except for Publications and a development of an Aquaculture Situation and Outlook Report, is summarized in Table 1 below (pages 7-8).

During this reporting period, the Publications Office at ISU produced and distributed a number of publications including fact sheets, technical bulletins, videos, and two issues of the Centers newsletter, the *NCRAC Journal*. A complete list of all publications from this office is included in the Appendix under Extension.

Other areas of support by the Administrative Office during this reporting period included: monitoring research and extension activities and developing progress reports; preparing a compendium progress report for all five RACs; developing liaisons with appropriate institutions, agencies and clientele groups; preparing, in coordination with the other RACs, both written and oral testimony for the U.S. House Appropriations subcommittee on Agriculture, Rural Development, Food and Drug Administration, and Related Agencies hearing in Washington, D.C.; participating in the NCC; numerous oral and written presentations to both professional and lay audiences; and working with other fisheries and aquaculture programs throughout the North Central Region.

PROJECT DEVELOPMENT

A joint Program Planning meeting of the BOD, IAC, and TC is held every year in the early winter. The IAC, with input from the TC, generates a list of priority areas for consideration by the BOD. Using their recommendation as guidelines, the BOD then selects priority areas for which project outlines will be developed. The BOD also specifies a maximum funding level for each priority area. Problem statements and objectives are then developed for each priority area by IAC and TC members at the Program Planning meeting. For projects with more than one objective, the IAC ranks the objectives by priority. The problem statement and objective(s) are then included in a workshop announcement that is broadly distributed throughout the North Central Region. The workshops are one-day events to establish a work group that will develop a project outline over the summer months. Work group members will be those who have demonstrated that they have the expertise and facilities for undertaking the proposed work in regard to a particular objective or objectives. The proposed work cannot deviate from the objective or objectives included in the workshop announcement. The work group elects a chair and secretary. The chair is responsible for submitting the project outline to the NCRAC Director; the secretary is responsible for preparing minutes from the workshop that are distributed to all attendees. All project outlines are peer reviewed. The reviewers' comments are used by the BOD in making the final selection of projects and level of funding at the following year's annual Program Planning meeting. All work group members are apprised of the BOD decisions. Revisions of projects approved by the BOD are submitted by the work group chair to the NCRAC Director. The revised project outlines are then included in a POW that is submitted to USDA. Upon approval by USDA, the Center issues subcontracts to the funded work group members.

TIME FRAME

- Program Planning meeting: early winter.
- Workshops: late-spring, early summer.
- Project outlines developed over the summer by work group members who participated in the workshops. These project outlines are then submitted to the Center in the fall and peer reviewed.
- The Board of Directors at the following year's Program Planning meeting selects the projects to be funded.
- Project outline revised and submitted to the Center by May.
- Revised projects are then submitted in June as a POW to USDA for approval. Once approved by USDA subcontracts are let by the Center with a start date of September 1.

By following this procedure, it takes approximately 18 months from the time of identifying a priority area until inception of a project to address the issue in question.

WORKSHOPS

The purpose of the workshops is to bring together those who are best qualified to work on project objectives by virtue of a demonstrated record of expertise and access to facilities required in the project. These people form a work group for the purpose of writing a project outline to address the problem in question. The following criteria typically apply to those projects that are funded by NCRAC.

- Involves participation by two or more states in the North Central Region;
- requires more scientific manpower, equipment, and facilities than generally available at one location;
- approach is adaptable and particularly suitable for inter-institutional cooperation resulting in better use of limited resources and a saving of funds;
- will complement and enhance ongoing extension and research activities by participants, as well as offer potential for expanding these programs;
- is likely to attract additional support for the work which is not likely to occur through other programs and mechanisms;
- is sufficiently specific to promise significant accomplishments in a reasonable period to time (usually up to 2 years);
- can provide the solution to a problem of fundamental importance or fill an information gap;

- can be organized and conducted on a regional level, assuring coordinated and complementary contributions by all participants.

The NCRAC program pays no overhead to participating institutions nor tuition remission, has no brick-and-mortar money, and relies on in-place salaried personnel, equipment, and facilities to carry out the projects. Due to the collaborative and cooperative nature of these regional projects, no one individual or institution receives a significant portion of the total project funds.

PROJECT REPORTING

As indicated in Table 1, the Center has funded a number of projects for many of the project areas. For example, there have been five separately funded projects in regard to Extension and six for Walleye. Project outlines have been written for each separate project within an area, or the project area itself if only one project. These project outlines have been submitted in POWs or amendments to POWs for the grants as indicated in Table 1. Many times, the projects within a particular area are merely continuations of previously funded activities; while at other times they are addressing new objectives. Presented below are Progress or Termination Reports for all projects that were underway or completed during the period September 1, 1994 to August 31, 1995.

All publications, manuscripts, or papers for the different project areas are listed in the Appendix.

Table 1. North Central Regional Aquaculture Center funded projects.

Project Area	Project Number	Duration	Funding Level	Grant Number
Extension	1		$39,221	88-38500-3885
	2	5/1/89-4/30/91	$68,389	89-38500-4319
	3		$94,109	91-38500-5900
	4	3/17/90-8/31/91	$110,129	91-38500-5900
	5		$14,275	92-38500-6916
		9/1/91-8/31/93	$25,725	95-38500-1410
			$351,848	
		9/1/93-8/31/95		
		9/1/95-8/31/97		
Economics and Marketing	1		$127,338	88-38500-3885
		5/1/89-12/31/91	$34,350	89-38500-4319
	2		$53,300	91-38500-5900
	3		$40,000	93-38500-8392
		9/1/91-8/31/93	$254,988	
		9/1/93-8/31/95		
Yellow Perch	1		$76,957	88-38500-3885
		5/1/89-8/31/91	$85,723	89-38500-4319
	2		$92,108	90-38500-5008
	3		$99,997	91-38500-5900
	4	6/1/90-8/31/92	$150,000	93-38500-8392
	5		$200,000	95-38500-1410
		9/1/91-8/31/93	$704,785	
		9/1/93-8/31/95		
		9/1/95-8/31/97		
Hybrid Striped Bass	1		$68,296	88-38500-3885
		5/1/89-8/31/91	$68,114	89-38500-4319
	2		$101,000	90-38500-5008
	3		$96,550	91-38500-5900
	4	6/1/90-8/31/92	$168,000	93-38500-8392
	5		$160,000	95-38500-1410
		9/1/91-8/31/93	$661,960	
		9/1/93-8/31/95		
		9/1/95-8/31/97		
Walleye	1		$177,517	89-38500-4319
	2	5/1/89-8/31/91	$111,657	90-38500-5008
	3		$109,223	91-38500-5900
	4	6/1/90-8/31/92	$75,000	89-38500-4319
	5		$150,000	93-38500-8392
	6	9/1/91-8/31/92	$117,897	94-38500-0048
			$57,103	95-38500-1410
		9/1/92-8/31/93	$798,397	
		9/1/93-8/31/95		
		9/1/95-8/31/97		
Sunfish	1		$130,758	90-38500-5008

Project Area	Project Number	Duration	Funding Level	Grant Number
	2 3	6/1/90-8/31/92 9/1/92-8/31/94 9/1/94-8/31/96	$149,867 $174,999 $455,624	92-38500-6916 94-38500-0048
Salmonids	1 2 3	6/1/90-8/31/92 9/1/92-8/31/94 9/1/94-8/31/96	$9,000 $120,799 $149,997 $200,000 $479,796	89-38500-4319 90-38500-5008 92-38500-6916 94-38500-0048
NCR Aquaculture Conference	1	6/1/90-12/31/91	$7,000	90-38500-5008
National Aqua. Extension Workshop	1	10/1/91-9/30/92	$3,005	89-38500-4319
Crayfish	1	9/1/92-8/31/94	$50,000	92-38500-6916
Baitfish	1	9/1/92-8/31/94	$62,000	92-38500-6916
Effluents	1	9/1/92-8/31/94	$153,300	92-38500-6916
Aquaculture Drugs (INADs/NADAs)	1	9/1/93-8/31/94 9/1/94-8/31/95	$2,000 $5,000 $7,000	89-38500-4319 94-38500-0048

PROJECT TERMINATION OR PROGRESS REPORTS

EXTENSION

Progress Report for the Period
May 1, 1989 to August 31, 1995

NCRAC FUNDING LEVEL: $311,848 (May 1, 1989 to August 31, 1995)

PARTICIPANTS:

Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin
James E. Ebeling	Ohio State University	Ohio
Donald L. Garling	Michigan State University	Michigan
Jeffrey L. Gunderson	University of Minnesota	Minnesota
F. Robert Henderson	Kansas State University	Kansas
Anne R. Kapuscinski	University of Minnesota	Minnesota
Terrence B. Kayes	University of Nebraska-Lincoln	Nebraska
Ronald E. Kinnunen	Michigan State University	Michigan
Christopher C. Kohler	Southern Illinois University-Carbondale	Illinois
David J. Landkamer	University of Minnesota	Minnesota
Joseph E. Morris	Iowa State University	Iowa
Kenneth E. Neils	Kansas State University	Kansas
Robert A. Pierce II	University of Missouri	Missouri
Daniel A. Selock	Southern Illinois University-Carbondale	Illinois
LaDon Swann	Purdue University	Indiana/Illinois
Administrative Advisor:		
David C. Petritz	Purdue University	Indiana

PROJECT OBJECTIVES

(1) Strengthen linkages between North Central Regional Aquaculture Center (NCRAC) research and extension work groups.

(2) Enhance the North Central Region (NCR) aquaculture extension network for aquaculture information transfer.

(3) Provide in-service training for Cooperative Extension Service (CES) and Sea Grant personnel and other landowner assistance personnel.

(4) Develop and implement aquaculture education programs for the NCR.

(5) Participate in development of NCRAC publications.

ANTICIPATED BENEFITS

The NCRAC Extension Work Group will promote and advance commercial aquaculture in a responsible fashion through an organized education/training outreach program. The primary benefits will be:

- increased public awareness through publications, short courses, and conferences regarding the potential of aquaculture as a viable agricultural enterprise in the NCR;
- technology transfer to enhance current and future production methodologies for selected species, e.g., walleye, hybrid

striped bass, yellow perch, salmonids, and sunfish, through hands-on workshops and field demonstration projects;
- improved lines of communication between interstate aquaculture extension specialists and associated industry contacts; and
- enhanced legal and socioeconomic atmosphere for aquaculture in the NCR.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1

Due to the efforts of aquaculture extension personnel in the NCR, NCRAC's Board of Directors formally adopted guidelines for Extension's involvement in all Center funded projects. These guidelines integrate research and extension activities so that Extension service personnel can better serve their clientele groups.

In addition, aquaculture Extension Work Group members have:

- Helped conduct a survey of crayfish producers in the NCR and completed a report on *Orconectes immunis* for inclusion in the Crayfish Work Group report.
- Provided the NCRAC Economics and Marketing Work Group with information relevant to that group's efforts to develop cost of production budgets and expected revenues for the commercial production of food-sized hybrid striped bass, walleye, and yellow perch in the NCR.
- Assisted in writing and developing the NCRAC Walleye Culture Manual that is being edited by Bob Summerfelt of Iowa State University.

OBJECTIVE 2

The demand for aquaculture extension education programs cannot be met by the few specialists in the NCR (4.0 FTE). Networking of specialists and CES designated contacts has maximized efficiency of education programs and minimized duplication. The NCRAC Extension Project is designed to assess and meet the information needs of the various clientele groups through cooperative and coordinated regional educational programming.

Aquaculture handbooks have been developed and distributed to each NCRAC designated aquaculture extension specialist and selected CES and Sea Grant field staff.

As with any organization, there have been changes in NCRAC extension personnel since the inception of the project. Landkamer was the primary aquaculture extension contact for Minnesota. However, he left the university and Kapuscinski became the primary contact person. Recently, Gunderson has assumed that responsibility. Two other individuals, who had served since the outset of the project as their state's aquaculture extension contact, were replaced in 1994. In Kansas, Neils replaced Henderson and in Illinois, Kohler replaced Selock.

OBJECTIVE 3

In-service training for CES and Sea Grant personnel and other landowner assistance personnel have been held in most of the states in the region. Training has been in the areas of basic aquaculture and safe seafood handling including HACCP (Hazard Analysis Critical Control Point).

OBJECTIVE 4

A number of workshops, conferences, videos, field-site visits, hands-on training sessions, and other educational programs have been developed and implemented.

There have been workshops on general aquaculture, fish diseases, commercial recirculation systems, aquaculture business planning, crayfish culture, pond management, yellow perch and hybrid striped bass culture, rainbow trout production, and polyploid induction in sunfish held in the region.

Two North Central Aquaculture Conferences (NCAC) have been held. The first in Kalamazoo, Michigan was held in March 1991. The second was held in February 1995 in Minneapolis, Minnesota. These regional meetings were attended by hundreds of individuals including persons from Canada.

On April 10, 1993, over 700 viewers from 35 states and Canada watched the first national interactive teleconference on aquaculture, "Investing in Freshwater Aquaculture" that was broadcast from Purdue University. It was a televised satellite broadcast for potential fish farmers. The program consisted of 10 five- to seven-minute video tape segments which addressed production aspects of channel catfish, crayfish, rainbow trout, hybrid striped bass, tilapia, yellow perch, baitfish, and sportfish. A set of course materials was available prior to the program. Three times during the program, a question and answer period was available to the audience through a toll free telephone number. Questions not answered during the program were answered by mail afterwards. The entire teleconference is available as a videotape from NCRAC's Publications Office as well as two other videotapes by the University of Nebraska-Lincoln that are reprises of the broadcast.

OBJECTIVE 5

Numerous fact sheets, technical bulletins, and videos have been written or produced by various participants of the Extension Work Group. These are listed in the Appendix.

WORK PLANNED

Efforts will continue in regard to strengthening linkages between research and extension work groups as well as enhancing the network for aquaculture information transfer. Participants will also continue to provide in-service training for CES, Sea Grant, and other land-owner assistance personnel. Educational programs and materials will be developed and implemented. This includes a workshop on hybrid striped bass (proceedings and videos), a walleye culture manual, yellow perch culture guide and videos, a marketing video for aquaculture products, and a production guide and videos about sunfish.

Additional workshops developed and hosted by state extension contacts will be advertised in surrounding states to take advantage of the NCRAC extension network and the individual expertise of Extension Work Group participants.

Several NCRAC fact sheets, technical bulletins, and videos will be developed by various Work Group members.

IMPACTS

- In-service training for CES and Sea Grant personnel has enabled those professionals to respond to initial, routine aquaculture questions from the general public.
- Development of aquaculture education programs for the NCR has provided "hands-on" opportunities for prospective

and experienced producers. Approximately 5,000 individuals have attended workshops or conferences organized and delivered by the NCRAC Extension Work Group. Clientele attending regional workshops learned of aquaculture development strategies in other areas of the country and acquired information which was of direct use to their own enterprises. Education programs also created situations where problems encountered by producers were expressed to extension personnel who later relayed them to researchers at NCRAC work group meetings for possible solutions through the research effort.

- Fact sheets, technical bulletins, and videos have served to inform a variety of clients about numerous aquaculture practices for the NCR. For instance, "Making Plans for Commercial Aquaculture in the North Central Region" is often used to provide clients with initial information about aquaculture, while species specific publications on walleye, trout, and catfish have been used in numerous regional meetings and have been requested by clients from throughout the United States. Publications on organizational structure for aquaculture businesses, transportation of fish in bags, and others are beneficial to both new and established aquaculturists. In a 1994 survey, NCRAC extension contacts estimated that NCRAC publications were used to address approximately 15,000 client questions annually.
- NCRAC extension outreach activities have helped to foster a better understanding and awareness for the future development of aquaculture in the region.

PUBLICATIONS, MANUSCRIPTS, WORKSHOPS, AND CONFERENCES

See Appendix.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVERSITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1989-90	$39,221	$66,992				$66,992	$106,213
1990-91	$68,389	$70,065				$70,065	$138,454
1991-93	$94,109	$152,952				$152,952	$247,061
1993-95	$110,129	$198,099		$250,000	$55,000	$503,099	$613,228
TOTAL	$311,848	$488,108		$250,000	$55,000	$793,108	$1,104,956

ECONOMICS AND MARKETING

Progress Report for the Period
September 1, 1993 to August 31, 1995

NCRAC FUNDING LEVEL: $40,000 (September 1, 1993 to August 31, 1995)

PARTICIPANTS:

Susan B. Kohler	Southern Illinois University-Carbondale	Illinois
Marshall A. Martin	Purdue University	Indiana
Patrick D. O'Rourke	Illinois State University	Illinois
Jean R. Riepe	Purdue University	Indiana
Extension Liaisons:		
Donald L. Garling	Michigan State University	Michigan
Terrence B. Kayes	University of Nebraska-Lincoln	Nebraska
Daniel A. Selock	Southern Illinois University-Carbondale	Illinois
LaDon Swann	Purdue University	Indiana

PROJECT OBJECTIVE

Develop cost of production budgets and expected revenues for the raising of food-sized walleye, yellow perch, and hybrid striped bass on farms in the North Central Region (NCR).

ANTICIPATED BENEFITS

The overall goal of this collaborative project is to enhance walleye, yellow perch and hybrid striped bass production by developing enterprise budgets for production of these species in the NCR. This supports the mission of NCRAC, especially by conducting research "for the enhancement of viable and profitable commercial aquacultural production in the United States for the benefit of producers, consumers, and the American economy."

The cost of production or budgeting components of this project offers the potential to help in identifying production systems for walleye, yellow perch and hybrid striped bass which are most likely to be commercially viable. Information on production costs is quite limited for these species, especially walleye and yellow perch. Enterprise budgets will enable producers to access the needed budget costs for comparisons for their own operation, for a new enterprise, or for increased production in their present facility in comparison to reasonable expectations about market prices.

This project will benefit the aquaculture industry in the NCR in several ways, even though there are some limitations of these budgets given the "emerging" status of the industry and given the nature of budgets.

- First, objectively developed cost information is typically more accurate than subjectively developed cost information or no information on costs at all. These budgets will give producers an idea of how enterprise budgets should be organized, what types of data need to be collected, and why good record keeping is essential. The production values and relationships upon which the cost structure is based, while not standardized in the industry, should serve as a rough rule-of-thumb by which aquacultural producers can gauge their management skills.

- Second, enterprise budgets are an excellent management tool for producers. If the publication of these budgets stimulates potential and current aquacultural producers to put together budgets that reflect their unique enterprises, then the industry will be much better off.
- Third, enterprise budgets are the cornerstone for all different types of financial analysis of aquaculture operations. The budgets will allow more economic research into financial aspects of aquaculture and enable those producers who are spurred on to put together budgets to push on into their own financial analysis (another management tool).
- Fourth, enterprise budgets are also the cornerstone for sensitivity analysis (yet another management tool). Undertaking sensitivity analysis will enable economists and producers to better understand the relative importance of cost and production items in the budget and to explore the boundaries of enterprise profitability.
- Finally, realizing that the budgets produced under the auspices of this project will not be the final, definitive budgets for aquaculture production in the NCR, they will serve as a solid starting base from which to update information and expand into alternative species, production systems, life stages, etc.

In a more indirect way, the enterprise budgets will accomplish two other important things.

- One, the budgets may help guide research and extension decisions by NCRAC work group participants, the Industry Advisory Council, the Board of Directors, and the supporting committees.
- Second, the budgets will provide an opportunity for the economists and other personnel developing the budgets to interact with aquaculture producers, researchers, and extension personnel in the NCR. This type of interdisciplinary interaction is vital for the improved understanding and communication of all vital aspects of aquaculture in the NCR.

Economic feasibility analysis will help producers evaluate technical advances in fish production. This contribution is critical as a guide to future research funding in the various species and production systems suitable for commercial production. The distribution of research results from this project through the publications of the Economics and Marketing Work Group and through the Extension Liaisons using computer budget software will provide a structured and informed dissemination system which is credible with producers, financial institutions and others.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

HYBRID STRIPED BASS

Kohler has compiled a review of the literature on hybrid striped bass (HSB) production and production costs. The literature reviewed is summarized in an annotated bibliography. This bibliography will be available to anyone needing the information.

HSB cost of production estimates were developed from six published reports on HSB production. These estimated costs will be presented at the NCRAC HSB Workshop in November 1995 and will be submitted for possible release as an NCR publication.

WALLEYE

O'Rourke and Illinois State University (ISU) graduate students have completed an extensive walleye production/culture literature review. The primary focus of the literature review was to find any research findings that might be useful in ascertaining the cost of production for walleye fingerlings and food-sized fish under intensive and extensive culture regimes. Very little economic research was found and even less was found that was documented well enough to be useful.

The second source of information was a survey of research experts and hatchery personnel familiar with walleye culture. The ISU investigators were surprised that many of the "experts" were as reluctant to share information as were most entrepreneurs/producers. The experts were selected and queried using a modified Delphi approach for both the fingerling and food-sized studies. This stage of the research was completed in 1995 with additional follow-up questions and identification of a broader group of "experts."

Work has advanced on identifying and analyzing the cost of production for advanced walleye fingerlings and food-sized walleye in intensive and extensive culture systems. The first Master’s thesis was finished in December 1994. It is an economic feasibility analysis of a tank based intensive walleye fingerling production system. The second Master’s thesis, an economic feasibility analysis of a tank based intensive food-sized walleye system, was finished in August 1995.

YELLOW PERCH

Riepe submitted a manuscript to NCRAC for publication as an extension technical bulletin. This publication reports the results of her research into the costs of culturing yellow perch. The manuscript is based on cost estimates for growing out advanced fingerlings within one growing season. Cost estimates were generated for two types of production systems: cages and levee ponds; and two sizes of operations: 2,268 kg (5,000 lb) and 22,680 kg (50,000 lb).

Sensitivity analysis also was conducted to test the impact of alternative budget parameters (production values and individual cost items) on the overall break-even price. A Master’s graduate student was assigned to conduct research in costs of producing perch in recirculating tank systems and a thesis was completed in 1995. Costs of growing out yellow perch in recirculating tank systems were analyzed for two sizes of operations: 1,588 kg (3,500 lb) and 2,268 kg (5,000 lb).

While developing cost estimates for yellow perch aquaculture, Riepe investigated feed and fingerling prices and procurement with various suppliers. Riepe used this information to develop tables estimating delivered prices for feed and fingerlings at five hypothetical producer locations around the North Central Region.

Following the technical bulletin, Riepe developed a fact sheet focusing on pond production costs and a fact sheet focusing on managing feed costs. The fact sheet on costs of pond production was a simplified, extension version of the pond enterprise budgets and discussion included in the technical bulletin. The fact sheet on managing feed costs was developed based on Riepe's conversations with feed manufacturers as well as the price and transportation data they provided.

WORK PLANNED

The distribution of research results from this project through various publications and through the Extension Liaisons using computer budget software will provide a structured and informed dissemination system which is credible with producers, financial institutions and others.

Kohler will submit the annotated bibliography on hybrid striped bass for publication. The HSB production cost estimates, which were developed from the literature review and farm visits, will be presented at an NCRAC HSB workshop in November 1995.

O'Rourke will continue economic analysis of walleye fingerling and food-sized fish production systems. Results from the two Master's theses studies will be submitted for technical bulletin and/or fact sheet publication through NCRAC and professional presentations.

Riepe received comments back from NCRAC reviewers on all three submitted manuscripts in mid-October 1995. She plans to revise manuscripts and submit them for publication in October - December 1995.

IMPACTS

Extension Liaison Don Garling hosted a yellow perch aquaculture workshop in June 1995. The results of Riepe's work on perch production costs were presented at that workshop. Attendees indicated that they were considering the types of systems modeled by Riepe. O'Rourke presented the preliminary results of the work on walleye fingerling tank based system cost of production at the Combined North Central and Ninth Annual Minnesota Aquaculture Conference in February 1995. Finally, Kohler will present the results of the review of HSB production costs at the NCRAC Hybrid Striped Bass Workshop in November 1995.

The information developed and presented for the three species is anticipated to be directly useful to the attendees as they consider their own operations and intentions in light of the cost data presented.

This project has already benefited the aquaculture industry in the NCR through the workshop presentations. As a result of this project, economists have been able to develop and deliver presentations on economic issues in aquaculture production to current and potential aquacultural producers. These presentations and the publications which follow may reduce the impacts of uninformed investment decisions by current and potential aquaculture entrepreneurs.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED

See Appendix.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1993-94	$22,104	$35,829				$35,829	$57,933
1994-95	$17,896	$23,854				$23,854	$41,750

TOTAL	$40,000	$59,683				$59,683	$99,683

YELLOW PERCH

Progress Report for the Period
September 1, 1993 to August 31, 1995

NCRAC FUNDING LEVEL: $150,000 (September 1, 1993 to August 31, 1995)

PARTICIPANTS:

Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin
Paul B. Brown	Purdue University	Illinois
Konrad Dabrowski	Ohio State University	Ohio
Terrence B. Kayes	University of Nebraska-Lincoln	Nebraska
Jeffrey A. Malison	University of Wisconsin-Madison	Wisconsin
Extension Liaison:		
Donald L. Garling	Michigan State University	Michigan
Non-funded Collaborators:		
Harlan Bradt, etc.	Coolwater Farms, LLC, Cambridge	Wisconsin
William Hahle	Pleasant Valley Fish Farm, McCook	Nebraska
John Hyink/John Wolf	Alpine Farms/Glacier Springs Trout Hatchery	Wisconsin
Dave Smith	Freshwater Farms of Ohio, Inc., Urbana	Ohio
Michael Wyatt	Sandhills Aquafarm, Keystone	Nebraska

PROJECT OBJECTIVES

(1) Determine the commercial scale feasibility and improve on the best intensive tank and pond culture practices for the production of yellow perch fingerlings.

(2) Determine the commercial scale feasibility of raising food-size yellow perch in flow-through raceways or tanks, open ponds, and large net-pens, comparing the best available formulated diets.

ANTICIPATED BENEFITS

At the 1992 Program Planning Meeting of the North Central Regional Aquaculture Center (NCRAC), the NCRAC Industry Advisory Council advanced the position that the primary emphasis of research projects proposed for the 1993-1995 funding period should be on the demonstration of commercial-scale feasibility of the best available research-based production technologies, working in collaboration with private fish producers. The NCRAC Board of Directors supported that position, and the NCRAC Yellow Perch Work Group responded by developing a project centered largely on conducting such demonstrations. This project is aimed at providing much needed information on the practical feasibility and costs of employing, on a commercial-scale, selected fingerling production and grow-out strategies that were initially developed and/or tested on a small (laboratory) scale. In addition, this project will develop improved technologies for certain key facets of yellow perch aquaculture. Finally, the results of experiments incorporated into this project will immediately help fish farmers improve the production efficiency of both fingerling and food-size yellow perch.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

As an integral component of much of this project, private producers were to provide the requisite facilities, fish, feed, day-to-day husbandry, and routine data collection. At its inception, this project included the participation of eight different private fish farms in various parts of the North Central Region (NCR). Participating university researchers were to provide project oversight on experimental design, advice or direct assistance with the technical set-up of any specialized experimental systems, supervision and assistance on critical end-point data collection, and analyses of results.

In Year 1 of the project (September 1, 1993 to August 31, 1994), significant progress was made at certain sites at testing selected research-based production technologies. Accordingly, from an extension perspective, the project is successfully building and/or expanding working relationships between NCRAC researchers and certain regional fish farmers, testing various research-based technologies under practical production conditions, transferring knowledge from academia to the private sector, and identifying private producers who are both capable and willing to sustain a collaborative technology evaluation and demonstration effort. Several of the original private-sector collaborators have either met or have worked hard to meet their project commitments.

However, from the research perspective, the likelihood of the project generating significant amounts of comprehensive feasibility-assessment data that will be publishable in peer-reviewed journals seems low, based on Year 1 results. One primary reason for this development is that several private-sector collaborators who had initially agreed to participate in the project have either partially or totally pulled back from their original commitments. The reasons for these pullbacks range from initially exaggerated claims of facility and other resource capabilities, to lack of sufficient technical competence or experience, to a belated realization of the potential risks involved. To deal with this problem, in some instances alternate private sector collaborators were sought for studies conducted in Year 2 (September 1, 1994 to August 31, 1995), and in other cases feasibility assessments will be conducted under laboratory conditions rather than under field conditions as originally proposed.

OBJECTIVE 1

Researchers at the University of Wisconsin-Milwaukee (UW-Milwaukee) directed their efforts during the first year of the study at improving the intensive culture technology for yellow perch. In part, these results were applied to a commercial production operation using Recirculating Aquaculture Systems (RAS) technology.

In January 1995, Alpine Farms installed a 29,000 L (7,661 gal) Aqua-Manna type RAS and is using it to demonstrate the grow-out of fingerling perch to market size. In February 1995, this system was stocked with approximately 10,000 (50-75 mm; 1.97-2.95 in) yellow perch fingerlings (total 14 kg; 30.9 lb). Following stocking, some initial mortality occurred due to inadequate preconditioning and maturation of the biofiltration system and entrainment of small-sized fish on the clarifier filtration mechanism. A surplus of perch fingerlings was used to stock the tank to its original number of fish. Un-ionized ammonia levels during this period necessitated periodic water exchanges. By March, the fish were feeding and ammonia concentrations had stabilized as the biofiltration system matured. Mean water quality parameters (and range) from 228 days of operation were 22.0°C (17.8 - 24.4; 71.6°F, 64.0 - 75.9; *N* = 210), 6.0 mg dissolved oxygen/L (5.2 - 9.0, *N* = 207), pH 7.0 (6.1 - 8.1, *N* = 197), 0.003 mg/L NH_3 (0 - 0.156, *N* = 194), and 0.165 mg/L NO_2 (0 - 0.8, *N* = 93). Feeding was continually adjusted based on food acceptance and variations in water quality. Ration levels eventually stabilized at 1.0 to 2.0% of body weight. Perch were periodically subsampled from the RAS for growth and food conversion estimates. Overall growth in length was between 0.5 and 0.6 mm (0.020 and 0.024 in) per day as would be expected for perch reared at these temperatures. Overall food conversion was 0.9 kg feed (dry): kg perch gain (wet). Similar conversions have been obtained in other intensive flow-through tank rearing units with similar feeds. Further trials at higher densities are needed to fully evaluate the rearing performance of yellow perch in this type RAS system.

Studies on pond fingerling production by the University of Wisconsin-Madison (UW-Madison) were conducted using ponds of various sizes at Coolwater Farms, LLC and the Lake Mills State Fish Hatchery. These studies evaluated the use of (1) selected high fry stocking densities and early pond harvest to maximize pond fingerling production, and (2) underwater lights and vibrating feeders to habituate perch fingerlings to formulated feeds while they remain in ponds.

The production of 17-22 mm (0.67-0.87 in) total length (TL) fingerlings (the smallest size at which perch can be habituated to conventional starter feeds) not habituated to formulated feeds in ponds with high initial fry stocking rates (e.g., 1,000,000 fry/hectare; 404,700 fry/acre) averaged 375,000 fingerlings/ha (151,763 fingerlings/acre). Other studies showed that feed training of fingerlings at this size in tanks resulted in about 60% survival. Accordingly, the maximum production of feed-trained perch fingerlings using the best available tandem pond/tank methods was about 225,000 fingerlings/ha (375,000 × 60%) (91,058 fingerlings/acre).

The production of feed-trained fingerlings from ponds equipped with underwater lights and automatic feeders was as follows: (1) ponds stocked at 1,000,000 fry/ha (404,700 fry/acre) averaged 320,000 fingerlings/ha (129,504 fingerlings/acre) (i.e., a 32% return); (2) ponds stocked at 2,000,000 fry/ha (809,400 fry/acre) averaged 400,000 fingerlings/ha (161,880 fingerlings/acre) (i.e., a 20% return); and (3) ponds stocked at ≥ 3,000,000 fry/ha (1,214,000 fry/acre) averaged 76,000 fingerlings/ha (30,757 fingerlings/acre) (an average 2.5% return). The poor survival of fingerlings in ponds stocked at ≥ 3,000,000 fry/ha (1,214,000 fry/acre) apparently resulted from high starvation rates of fish prior to the habituation to feeding formulated feeds. This starvation, in turn, resulted from a decline in the natural forage base caused by excessive fish densities. All ponds were harvested shortly after large numbers of fish exhibited an aggressive feeding response, at which time the fingerlings were 30-45 mm (1.18-1.77 in) TL. Based on tests conducted in tanks, virtually all of the fingerlings harvested were habituated to formulated food. The wide size range among harvested fingerlings suggests that feeding methods and strategies have a profound effect on the survival and growth of fingerling perch habituated to formulated feeds in ponds.

To address this latter problem, UW-Madison investigators developed and began preliminary tests of an improved pond light and feeding system. The new system is designed to address the problems of reliability and limited feed distribution that were inherent with the original design. Initial indications are that the new system is durable, has a wide feed distribution pattern, and requires less manpower for operation and maintenance.

University of Nebraska-Lincoln (UNL) efforts in Year 2 were focused on pond-production field trials conducted at Pleasant Valley Fish Farm, McCook, Nebraska. Particular emphasis was placed on replicating and improving on results obtained in Year 1 from field trials aimed at enhancing procedures for the commercial-scale production of yellow perch fry and fingerlings - including the habituation of advance fry to formulated feed and grow-out to advanced fingerlings in ponds. About 200,000 (2,500,000/ha; 1,011,750/acre) eyed-eggs or fry were stocked into two 0.08-ha × 1.5-m-deep (0.20-acre × 4.92-ft-deep) rectangular ponds which are drainable and can be supplied with groundwater to moderate temperature extremes. Both ponds were fertilized during the early fry production period (about 3 weeks) and were continuously aerated as described in the original proposal. After that, automatic vibrating feeders equipped with underwater lights and controlled by an electronic timing system were added to the ponds to habituate the fish to a starter trout diet (Sterling Silver Cup, Sterling H. Nelson & Son, Inc., Murray, Utah).

Two changes in procedures from those used in Year 1 were: (1) the number of feeding stations in each pond was increased from five to seven; and (2) in one pond, some advanced fry were concentrated in a net-pen around one of the feeders. Spring and early summer in Nebraska in 1995 were characterized by unseasonably cold weather, much more so than 1994. To compensate in part for the difference between years, a decision was made to delay the harvest of the two ponds from late September (as in 1994) to late October (1995). Because of this, specific numerical findings on growth and other production parameters have not yet been fully analyzed, and therefore are not available for this report. However, visual observations suggest that the percentage of large versus small perch harvested was significantly improved by the addition of more feeders to each pond. Also, the perch concentrated in the net-pen appeared to habituate to feed much more readily than fish ranging free in the ponds. No field trial to habituate young perch to formulated feed in tanks was done at the Pleasant Valley Fish Farm in 1995 because of a lack of sufficient time and funds to set up the necessary tanks and feeding systems.

Following the procedure developed during the first year of research, Ohio State University (OSU) researchers manually spawned yellow perch brood stock (2 year olds) during the months of April, May, and June 1995. Due to an unseasonably warm winter and cold spring and perhaps nutritional deficiencies, the egg quality was very poor with extremely low hatching rates and survival. A limited number of eggs were incubated and eyed-staged embryos stocked out into two 0.1 ha (0.25 acre) research ponds on May 15, 1995 at a density of approximately 100,000 embryos per pond. The ponds were fertilized weekly with 3 L (0.79 gal) 28-0-0 and 300 mL (0.36 gal) 10-34-0 inorganic fertilizer to stimulate and maintain algae and zooplankton production. Ponds were sampled at night with lights and small nets, but low survival rates prevented harvesting of sufficient numbers to repeat the Year 1 experiment. Both ponds were harvested after 9 weeks yielding approximately 5,500 fry with an average mean weight of 1.7 g (0.06 oz). These fry were used in a habituation study, to examine density effect of conversion to dry feed and survival rates.

Yellow perch fry with an initial mean weight of 1.7 g (0.06 oz) were stocked at four densities (7.7, 11.5, 15.4, 18.5 g/L) into 25-L (6.6-gal) round fiberglass tanks at 21°C (69.8°F) and were initially fed Zeiglers Brothers crumbles #2 via automatic feeders at a rate of 7% body weight . Water flow was maintained high enough to ensure good water quality and adequate dissolved oxygen levels. The yellow perch fry had been starved for one week prior to the start of the feeding trial which lasted for 28 days. During this time, almost no mortalities were observed in any of the tanks and growth rates were not significantly different for the four densities.

OBJECTIVE 2

The principal accomplishments for this project were introduction of yellow perch aquaculture to three new aquaculturists, and identification of feeds that when fed to advanced fingerlings results in maximum weight gain.

The UNL focus on this objective, in cooperation with Pleasant Valley Fish Farm, was to evaluate under commercial conditions the feasibility of rearing age-1 yellow perch fingerlings to market size in aerated ponds supplied with groundwater to maintain water quality and moderate pond water temperature. As noted under Objective 1, spring and early summer in Nebraska in 1995 were unusually cold. The cold period was followed by very hot weather from midsummer through early autumn. Because of these climatic extremes plus some marketing decisions by Pleasant Valley Fish Farm, a decision was made to defer harvest of these production ponds from mid-October to mid-November

So, as with Objective 1, specific numerical findings on growth and other production data are not yet available for this report. One major change in procedure from Year 1 was that instead of comparing two sinking diets (one formulated specifically for perch by Purdue University versus Sterling Silver Cup trout feed), a single floating trout feed (Sterling Silver Cup) was evaluated. Visual observations to date indicate that perch can be readily trained to a floating feed and appear to grow as well or better on it than on nutritionally similar sinking diets. Regardless, the field trials conducted at Pleasant Valley Fish Farm unequivocally confirm that yellow perch can be reared from egg to market size within two growing seasons - a time frame similar to catfish production in the South.

Established producers in Nebraska and new producers in Indiana participated in an evaluation of feeds for yellow perch. Those feeds were from established fish feed companies or feed mills located in the region exploring the possibility of expanding their product line. Producers in both states reported fish fed diets from the established feed mills grew better and converted feed more efficiently than fish fed diets from local mills. Additional research is underway with local mills to help them upgrade their manufacturing capabilities to meet the needs of the developing perch industry.

A controlled study was conducted at Purdue University in which advanced fingerling fish (mean average weight = 50 g; 1.76 oz) were fed a series of experimental and commercial diets. Two experimental diets were identified that, when fed to fish, resulted in weight gains of 84 or 103% of the weight gain of fish fed the best commercial diet. Several commercial diets were fed to perch in the same study, four of which were formulated to meet the requirements of rainbow trout. Fish fed one of the trout diets gained 63% more weight over the course of the study than fish fed the poorest trout diet. Fish fed either of two types of diets formulated for catfish grew significantly worse than fish fed the trout diets.

WORK PLANNED

A NCRAC grant entitled Advancement of Yellow Perch Aquaculture has been funded for the 95-97 biennium. Objectives of this project are designed to continue work to improve larval rearing techniques by developing and evaluating starter diets in relation to size at transfer to formulated feeds under selected environmental conditions, improve pond fingerling production through examination of in-pond feeding using physical/chemical attractants and improved harvesting strategies for different sized fingerlings from various types and sizes of ponds, and develop extension materials and workshops emphasizing techniques. However, work on this project will continue as described below.

OBJECTIVE 1

UW-Milwaukee will conduct a workshop that demonstrates the intensive culture of yellow perch fingerlings using a recirculating system and establish the production costs for this type of rearing unit. Publications describing all completed studies are currently being prepared. UW-Madison researchers will continue to study the production of feed-trained and advanced yellow perch fingerlings using in-pond feeding techniques as detailed under Objective 2 of the NCRAC grant funded for the 95-97 biennium entitled Advancement of Yellow Perch Aquaculture.

The analysis of the data collected by UNL investigators from the field trials on yellow perch fingerling production conducted at Pleasant Valley Fish Farm will be completed and the findings submitted for publication, probably as a communication or note in *The Progressive Fish-Culturist*, or possibly as a NCRAC technical bulletin.

OBJECTIVE 2

The UNL field trials at Pleasant Valley Fish Farm on the production of food-size yellow perch will be completed in mid November 1995; the fish will be harvested for sale in Wisconsin; the production data analyzed by UNL investigators, and the findings submitted for publication, probably as a communication or note in *The Progressive Fish-Culturist*, or possibly as a NCRAC technical bulletin.

IMPACTS

The preparation of a summary of production cost information by UW-Milwaukee investigators for the intensive culture of yellow perch fingerlings in tanks will provide the necessary framework for writing a business plan for private sector producers who intend on using this fingerling production strategy. In addition, the continual refinement of intensive fry culture protocols will improve the production efficiency of this method. Information was developed on the physical, chemical and biological aspects of yellow perch production using RAS technology.

Studies on pond fingerling production by

UW-Madison, UNL, and OSU researchers have shown that research-based production strategies can be used on a commercial scale to produce large numbers of perch fingerlings at a relatively low cost. The most promising of these strategies include the use of high fry stocking densities coupled with either (1) early pond harvest, for the subsequent habituation of fingerlings to formulated feeds in tanks; or (2) systems using lights and automatic feeders for habituating fingerlings to formulated feeds while they remain in ponds.

Studies at OSU have shown that pond produced yellow perch fry of 15-17 mm (0.59-0.67 in) in total length can be effectively weaned to practical trout diets at water temperatures of 21°C (69.8°F). Larger yellow perch fry (1.5-2.0 g; 0.05-0.07 oz) can also be weaned to trout diets following an initial period of starvation. This latter procedure reduces the mortalities due to stress and handling at a small size and allows for net harvesting or drain harvest of ponds.

The Nebraska field trials done collaboratively by the UNL and Pleasant Valley Fish Farm have clearly demonstrated that procedures developed or derived from earlier research projects can be utilized under commercial production conditions. Pleasant Valley Fish Farm, a major regional producer of yellow perch fingerlings, has benefited directly from new knowledge gained by participating in a NCRAC Yellow Perch Work Group project. At least one new fish farmer in Nebraska has begun producing food-size perch and is presently exploring market opportunities. Recently, a long-established Nebraska fish farmer has significantly increased his emphasis on the production of yellow perch. The number of inquiries about yellow perch aquaculture from Nebraskans and others in the NCR and Canada has increased noticeably in the past year.

The results of yellow perch research funded by NCRAC was presented at a workshop hosted at Spring Lake, Michigan in June of 1995. Presentations were made by four NCRAC researchers and two cooperators. The workshop was attend by over 50 prospective perch culturists from five States and one Canadian Province.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED

See Appendix.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1993-94	$75,000	$87,240	$30,000	$10,000[a]		$127,240	$202,240
1994-95	$75,000	$81,587	$30,000	$81,000[abc]		$192,587	$267,587
TOTAL	$150,000	$168,827	$60,000	$91,000		$319,827	$469,827

[a]Wisconsin Sea Grant/USDC/NOAA
[b]USDI, Bureau of Indian Affairs
[c]USEPA

HYBRID STRIPED BASS

Progress Report for the Period
September 1, 1993 to August 31, 1995

NCRAC FUNDING LEVEL: $168,000 (September 1, 1993 to August 31, 1995)

PARTICIPANTS:

Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin
George G. Brown	Iowa State University	Iowa
Paul B. Brown	Purdue University	Indiana
Konrad Dabrowski	Ohio State University	Ohio
James E. Ebeling	Ohio State University	Ohio
Terrence B. Kayes	University of Nebraska-Lincoln	Nebraska
Christopher C. Kohler	Southern Illinois University-Carbondale	Illinois
Jeffrey A. Malison	University of Wisconsin	Wisconsin
Robert J. Sheehan	Southern Illinois University-Carbondale	Illinois
Bruce L. Tetzlaff	Southern Illinois University-Carbondale	Illinois
R. Melvin White	Purdue University	Indiana
Extension Liaison:		
Joseph E. Morris	Iowa State University	Iowa
Non-Funded Collaborator:		
Fred Barrows	U.S. Fish and Wildlife Service, Fish Technology Center, Bozeman	Montana

PROJECT OBJECTIVES

(1) Develop larval diets and economically feasible techniques to convert hybrid striped bass young from zooplankton prepared diets.

(2) Develop intensive hatchery production techniques for white bass and to "domesticate" white bass by producing brood stock originating from induced spawns.

(3) Improve methods for storage and transport of striped bass and white bass gametes.

(4) Perfect cryopreservation techniques for white bass/striped bass semen and to demonstrate feasibility of hybrid striped bass production using "stored" semen in industry-type settings.

ANTICIPATED BENEFITS

The development of intensive larval culture techniques for white bass will allow for its full domestication, and will preclude the initial need for outdoor ponds. Because reciprocal cross hybrid striped bass are the same size as white bass at the swim-up stage, the results of this work will be directly applicable to their culture.

Conversion of larval fish to formulated feeds is one of the most difficult aspects of hybrid striped bass culture. Typically, high mortality and nonuniform acceptance of feed results. Thus, if flavor additives can be identified that entice consumption of feed, conversion to formulated feeds would be more uniform and lead to higher survival rates. Higher survival rates would result in higher profits for aquaculturists.

Development of efficient and reliable techniques to store, cryopreserve, and transport gametes (eggs and sperm) would improve breeding and production capabilities for culture technology of hybrid striped bass. Specifically, the development of these techniques will allow: (1) a continuous supply of gametes, (2) year-round production, (3) facilitation of selective breeding, and (4) more efficient use of available gametes. Although such methods need to be perfected for both semen and eggs, it is more likely that studies on semen will result in rapid development of technology for use in the aquaculture industry.

By working closely with a commercial producer in the region, it is hoped to directly transfer the developed semen storage technologies to the private sector, as well as satisfy future research objectives. This work, coupled with the out-of-season spawning work being conducted in our region and elsewhere, should greatly assist commercial producers to economically produce their own seed stock. Commercial producers would only need to maintain female brood stock of one of the species used in the cross. Sperm from the other species could be obtained elsewhere, stored until needed, and then used.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

Research at Purdue University was designed to formulate and mix dry dietary ingredients, and facilitate manufacturing small pellets with the help of colleagues at the U.S. Fish and Wildlife Service, Fish Technology Center, Bozeman, Montana. Three diets were formulated in the first year of this project that contained two distinctive flavor additives that would be considered legal to use. That task was accomplished and diets were sent to colleagues at Southern Illinois University-Carbondale (SIU-C) and the University of Wisconsin-Milwaukee (UW-Milwaukee).

In a comparative study conducted at SIU-C, hatching rates for embryos incubated in Heath trays (28.2%) were equivalent to tannic acid-treated (150 mg/L water) embryos incubated in Heath trays (22.9%) or McDonald jars (22.4%).

Facilities to intensively rear larval white bass were established at Ohio State University (OSU) , SIU-C, and UW-Milwaukee. White bass larvae from three separate spawning trials were shipped by overnight freight to OSU and UW-Milwaukee. Attempts to rear larval white bass were minimally successful. Less than 1% survival rates were obtained by day 122 at UW-Milwaukee, day 45 at OSU and day 24 at SIU-C.

A group of white bass sac-fry shipped from SIU-C to UW-Milwaukee was introduced evenly by volume into twelve 60-L (15.8 gal) flow-through aquaria. Each aquarium contained approximately 300 sac-fry. These fish were offered "green tank" water and the three experimental diets that were provided by Purdue University. The length of the cylindrical food particles ranged from approximately 0.5 mm to 1.7 mm (0.02-0.07 in) and the diameter was 420-595 µm. White bass sac-fry are approximately 3.5 mm (0.14 in) in total length. The cross sectional diameter of the feed approximated the width of the entire head (550-630 µm) of white bass sac-fry, and was outside of the range of the width of the mouth. UW-Milwaukee researchers ground portions of the diets in a mortar and pestle and sieved it through a 150 µm mesh to obtain more suitable-size particles. From May 26-31, 1995, each of the three ground and sieved diets was offered to fry in triplicate aquaria along with "green tank" water. The controls received only "green tank" water. No feeding activity or interest by the fry in the formulated diets was observed. Mortality of the sac fry was heavy in all the tanks and by May 31 (within 6 days), less than a dozen fry were observed in any of the aquaria and more than half of them had only one or no living fry. At this point the trial was terminated.

Past studies at Iowa State University (ISU) and SIU-C have allowed for evaluations of a number of semen extender and cryoprotectant solutions, and freezing and thawing methods. It was found that cryopreserved sperm showed promise for providing a cost-effective method for striped bass culturists to obtain seed stock. Studies at SIU-C showed that good fertility can be achieved in white bass eggs using cryopreserved spermatozoa.

Average fertility in several tests using white bass eggs fertilized with cryopreserved white bass sperm ranged from 22 to 48% of fertility with fresh, control semen. However, fertility was highly variable, and considerable motility was lost upon thawing frozen spermatozoa. Results with frozen striped bass spermatozoa and white bass eggs were better, but were also variable; average fertility for frozen striped bass spermatozoa ranged from 45 to 100% of control values.

Studies of sperm morphology at ISU indicated that some cryopreserved seminal samples (about 20% of those evaluated) showed clumping. Samples which exhibited clumping and adhesion showed no motility upon thawing, whereas samples where sperm morphology was normal and no clumping occurred became motile upon thawing. These results could explain much of the variability that has been observed in fertility tests, but it cannot be explained at this time why some samples undergo these adverse changes while others do not.

Studies at ISU also showed that best motility was routinely obtained when samples were activated with water prior to being completely thawed. This agrees with the results of fertility tests conducted at SIU-C; better fertility has routinely been obtained when cryopreserved semen is only partially thawed when combined with eggs.

In summer, 1995, Mississippi Fisheries, Inc. in Greenville, Mississippi, had a complete hybrid striped bass production failure, apparently due to the use of a new disinfectant. This company was supplying a major portion of the hybrid striped bass fingerling industry. Aquafutures, Inc., a Boston firm which annually raises over 1 million pounds of food-size hybrids, was not able to obtain sufficient numbers of fingerlings this year. In July 1995, a multi-state, interregional collaboration was initiated among SIU-C, University of Maryland and Aquafutures, Inc. SIU-C shipped white bass semen in extender solution to Dr. Zohar, University of Maryland. Dr. Zohar successfully induced a female striped bass to spawn and several million embryos were produced. Fertilization was over 70%. However, due to a severe heat wave which hit Baltimore two days later, all developing embryos were lost. Had fry been produced, Keo Fish Farm, in Keo, Arkansas, had agreed to rear the fry to fingerlings, and then to ship them to Aquafutures, Inc. An additional attempt will be made to accomplish this goal in

November 1995. Aquafutures, Inc. is currently making arrangements with Florida producers to rear the larvae to fingerling size. This project clearly demonstrates the advantages of photothermal manipulation of spawning time in fishes, as well as the use of stored semen. Had it not been for an untimely heat wave, a major inter-regional, university/industry success story would have occurred.

WORK PLANNED

The last spawning/larval rearing trials will be conducted in November 1995. A hybrid striped bass workshop is planned for November 4, 1995, at Champaign, Illinois. A termination report for these project objectives will be submitted in winter, 1996.

IMPACTS

The potential impacts of intensive larval rearing and larval diet research are increased profitability. If flavor additives can be identified, a higher percentage of larvae can be trained to accept the feed and more juveniles can enter the food fish production cycle.

Related to this domestication of brood stock, is the availability of suitable gametes for successful fish reproduction. Because striped bass are typically difficult to obtain, it would be highly advantageous for the aquaculturist to have access to gametes without the difficulty of collecting or transporting the parent fish. The successful induction of white bass spawns and subsequent storage and transportation of *Morone* species gametes should go far in advancing the hybrid striped bass industry in the North Central Region. These technological advancements, combined with the cooperation of a regional commercial producer, will be transferred to the private sector in the form of fact sheets, videos, and workshops.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED

See Appendix.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVERSITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1993-94	$81,000	$58,679				$58,679	$139,679
1994-95	$87,000	$60,761				$60,761	$147,761
TOTAL	$168,000	$119,440				$119,440	$287,440

WALLEYE

Progress Component Termination Report for the Period
September 1, 1989 to August 31, 1993

NCRAC FUNDING LEVEL: $321,740 (May 1, 1989 to August 31, 1993)

PARTICIPANTS:

Thomas G. Bell	Michigan State University	Michigan
Frederick W. Goetz, Jr.	University of Notre Dame	Indiana
David E. Hinton	University of California-Davis	California
Anne R. Kapuscinski	University of Minnesota	Minnesota
Terrence B. Kayes	University of Nebraska-Lincoln	Nebraska
Jeffrey A. Malison	University of Wisconsin-Madison	Wisconsin
Gary D. Marty	University of California-Davis	California
Robert J. Sheehan	Southern Illinois University-Carbondale	Illinois
Robert C. Summerfelt	Iowa State University	Iowa
Bruce L. Tetzlaff	Southern Illinois University-Carbondale	Illinois
Allan L. Trapp	Michigan State University	Michigan
Extension Liaison:		
Ronald E. Kinnunen	Michigan State University	Michigan
Non-funded Collaborators:		
Iowa Department of Natural Resources (DNR)	Bellevue Research Station	Iowa
Iowa DNR	Rathbun State Fish Hatchery	Iowa
Iowa DNR	Spirit Lake State Fish Hatchery	Iowa
Minnesota DNR	Devil's Track Hatchery	Minnesota
Nebraska Game & Parks Commission	Calamus State Fish Hatchery, Burwell	Nebraska
Ohio DNR	London State Fish Hatchery	Ohio
U.S. Fish & Wildlife Service	Garrison Dam National Fish Hatchery	North Dakota
U.S. Fish & Wildlife Service	Valley City National Fish Hatchery	North Dakota
U.S. Fish & Wildlife Service	Gavins Point National Fish Hatchery	South Dakota
U.S. Fish & Wildlife Service	Genoa National Fish Hatchery	Wisconsin

REASONS FOR TERMINATION

Objectives completed and funding terminated.

PROJECT OBJECTIVES

(1) Develop baseline information on the mechanisms regulating the natural reproductive cycle of wild and pond-held walleye by characterizing seasonal changes in hormone titers and gonadal histology.

(2) Develop methods for manipulating the annual reproductive cycle of walleye to

induce out-of-season spawning.

(3) Evaluate zooplankton seeding for pond culture of fingerling walleye.

(4) Evaluate strategies for control of clam shrimp in ponds used for culture of fingerling walleye.

(5) Determine the etiology of noninflation of the gas bladder of intensively cultured walleye fry.

PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1

The endocrine and gonadal changes during the annual reproductive cycle of walleye were described for the first time. No differences were observed between the developmental patterns of wild walleye (captured primarily from the Mississippi River near Minneapolis, Minnesota) and walleye held in ponds in Carbondale, Illinois. Gonadal growth in wild male walleye began in August/September, and testes contained mature spermatozoa by late fall (October/November). Mature spermatozoa could be expressed from males collected from January through April. Testosterone levels were low (<0.5 ng/mL) throughout the summer, rose in October to a plateau of >1.0 ng/mL from November through January, and peaked in March at 2.8 ng/mL. Serum levels of 11-ketotestosterone were <10 ng/mL from late April through January, and rose in March and early April to >35 ng/mL.

In wild female walleyes, oocytes increased in diameter from 184.0 $\pm$ 18.6 µm in October to 998.7 $\pm$ 39.8 µm in November. This increase occurred coincident with a marked rise in gonadosomatic indices (GSIs) and circulating levels of serum estradiol-17β (from 0.2 ng/mL to 3.7 ng/mL), the steroid responsible for stimulating hepatic vitellogenin synthesis in teleosts. Just prior to spawning in March, oocytes were approximately 1,500 µm in diameter. Following spawning, average GSIs in females declined from 15.3% to 1.5%. Data from *in vitro* cultures of walleye oocytes conducted at the University of Wisconsin-Madison (UW-Madison) suggested that 17α,20β-dihydroxy-4-pregnen-3-one (17,20-P) may be the steroid responsible for inducing final oocyte maturation in walleye. *In vivo* studies showed that 17,20-P levels rose very transiently to approximately 2 ng/mL coincident with final oocyte maturation. Taken together, these results suggest that vitellogenesis and spermatogenesis are at or near completion as early as mid-January, and that simple environmental and/or hormonal manipulations could be used to induce spawning from mid-January to late March.

OBJECTIVE 2

University of Nebraska-Lincoln (UNL) and UW-Madison investigators developed methods to manipulate the annual reproductive cycle and induce out-of-season spawning of walleye. Wild adult walleye were captured in autumn by the Nebraska Game and Parks Commission from Lake McConaughy, Elwood Reservoir, and Merritt Reservoir in Nebraska, and by the Iowa Department of Natural Resources (DNR) from the Mississippi River. The Nebraska fish were transported to the Calamus State Fish Hatchery near Burwell, Nebraska, where they were maintained in a lined pond. In early December, these fish were transferred to earthen ponds at the Gavins Point National Fish Hatchery near Yankton, South Dakota. Walleye captured from the Mississippi River were transported directly to the Gavins Point hatchery. All fish were fin-clipped to identify their origin, and transported by UNL personnel. At the

Gavins Point hatchery, the walleye were separated by sex and overwintered in two 0.07-ha (0.17-acre) ponds stocked with forage fish.

In January, February and March, 16-20 females and 4-5 males were recaptured from the Gavins Point hatchery ponds and transferred to the Calamus State Fish Hatchery, where they were placed in indoor tanks. There, the water temperature was gradually increased over a 10-d period to 10 °C (50°F) and the photoperiod was set at 12-h light/12-h dark. Females were subject to one of four injection regimes: (1) saline on days 0 and 2; (2) human chorionic gonadotropin (hCG) on day 0 and day 2; (3) a synthetic luteinizing hormone-releasing hormone analogue (LHRHa) on day 0 and day 2; or (4) hCG on day 0 and 17,20-P on day 2. No difference in response patterns to these treatments was observed in walleye of different origins.

At each month, all hormone injection regimes successfully induced GVBD (germinal vesicle breakdown) and ovulation in at least some of the females, whereas none of the saline-injected fish underwent GVBD or spawned. In January, hCG was the most effective treatment at inducing ovulation. In February and March, egg survival was the highest in hCG-treated fish. At all times, the 17,20-P treatment resulted in very low egg survival and small egg size. The results demonstrate that appropriate hormone and environmental treatments can be successfully used to induce spawning in walleye from late January through March. The most effective hormone treatment in this regard was hCG. Regardless of when it was used, hCG at 150 and 500 IU/kg (days 0 and 2, respectively) (68 IU/lb and 227 IU/lb) induced spawning 6-8 days after the last injection.

OBJECTIVE 3

Investigators at Iowa State University (ISU) conducted experiments in 1989 and 1990 to evaluate zooplankton seeding (inoculation) for pond culture of fingerling walleye at the Valley City National Fish Hatchery (VCNFH), Valley City, North Dakota, and Garrison Dam National Fish Hatchery (GDNFH), Riverdale, North Dakota. Zooplankton for the inoculation experiments were collected with an air-lift pump and cage system or by filtering inflowing water to raceways. In both cases, the zooplankton that were used for seeding the ponds were those large enough to be retained by a 0.5 mm (0.02 in) screen. All of the inocula consisted of cladocera (*Bosmina* and *Daphnia*) as well as cyclopoid and calanoid copepods.

The zooplankton inoculation was done during the first week after fry stocking. The zooplankton inocula ranged from 0.4 to 28.8 kg/ha, or 70 to 990 organisms per m^3 based on pond volume. In 1989, 95 to 100% of the inoculum was *Daphnia pulex*; in 1990, 77% of the inoculum used at Valley City was *Daphnia pulex*, but at Garrison Dam, only 13.5% were *Daphnia* and 67% were copepods. Over two years, 22 ponds were inoculated with zooplankton, and 22 ponds served as the controls (i.e., without zooplankton inoculation).

In each year and at both hatcheries, the average yield (kg/ha, and number/ha) of walleye fingerlings from ponds that had received the zooplankton inoculation was lower than the control ponds. The yield of walleye fingerlings (number per acre) from ponds receiving a zooplankton inoculation at the VCNFH in 1989 was 21.8% less than the control ponds, and 22.4% less in 1990; at GDNFH, the yield from ponds receiving the zooplankton inoculation was 50.9% less in

1989 and 66.9% in 1990 than the control ponds. Also, data combined over both years and both hatcheries showed that smaller biomass yield of fingerlings (42.7 kg/ha; 38.1 lb/acre) was obtained from ponds that were seeded with zooplankton than the control ponds that were not inoculated (54.9kg/ha; 49.0 lb/acre).

Overall, the findings indicate that zooplankton inoculation of culture ponds during the week fry are stocked had reduced fish production. These findings indicate that zooplankton inoculation as a pond management strategy must be undertaken with caution. Ponds should not be inoculated with large cladocera such as *Daphnia pulex* shortly after stocking walleye fry because the larger zooplankton in the inoculum have a competitive advantage over the smaller zooplankton copepod nauplii and other smaller zooplankton that serve as important prey for first feeding larval walleye. This does not mean that an inoculation with smaller zooplankton or use of larger zooplankton will not be desirable, however, the findings demonstrate that the timing of such methods for biomanipulation need to be carefully evaluated. At these hatcheries, the normal inflowing water carried an abundance of zooplankton, but if zooplankton populations are not abundant in the water used to fill the ponds (i.e., when ground water is used) or if zooplankton numbers decline during the culture interval, inoculation may be used to initiate or to sustain zooplankton populations. However, prior research on the effects and benefits of zooplankton inoculation is limited, and it has not been systematically studied in walleye fingerling culture.

OBJECTIVE 4

ISU investigators carried out studies on the ecology of clam shrimp at the GDNFH. In 1992, the studies were carried out on 23, 0.64-ha (1.58-acre) ponds during the culture season for northern pike, and 19 of the same ponds during the season for walleye. Ponds at the GDNFH were first used to raise northern pike. They were drained after 3 to 4 weeks to harvest the pike, then refilled to raise walleye. Adult clam shrimp were observed in 12 of the 23 ponds during northern pike culture, and 10 of the 19 ponds during walleye culture. Northern pike were cultured up to 29 days in ponds with clam shrimp, while pike were cultured a maximum of 22 days in ponds without clam shrimp. Survival and yield (number/ha, and number/pond) of northern pike was significantly lower in ponds with clam shrimp compared to ponds without clam shrimp. Similar differences, although not significant, were seen in walleye culture ponds. Northern pike and walleye were cultured longer in ponds with clam shrimp, implying that fish growth is reduced in culture ponds with clam shrimp. The majority of large clam shrimp found during the walleye culture season were most likely hatched during northern pike culture. When ponds are used in tandem to raise northern pike and walleye, to prevent development of clam shrimp during the walleye culture the ponds should be thoroughly dried between culture periods.

OBJECTIVE 5

Studies on the etiology (cause for) of noninflation of the gas bladder (NGB) were carried out as a collaborative effort among ISU, Michigan State University (MSU), and University of California-Davis (UCD). The study objectives included development of methods for intensive rearing of larval walleye on formulated feeds (ISU), identification of pathological lesions that will indicate the etiology of non-inflation of the gas bladder (MSU), and a description of developmental histology of the gas bladder, pneumatic duct, and other tissues and glands (UCD).

Each year, researchers at ISU obtained 1- to 5-day posthatch walleye fry or eyed-eggs from at least three cooperating state and federal fisheries agencies. ISU personnel reared walleye fry in an intensive culture environment and fed the fish a formulated feed, "fry feed Kyowa" (BioKyowa, Inc.), sizes B-400 through B-700, for 21-30 days. Each lot of fish obtained each year was used to evaluate different intensive culture treatments. Culture conditions involved different tank design (cylindrical and square), single-pass and recycle water systems, and pH. These different culture systems have aspects of them that may influence feed particle density (i.e., feeding success affects survival) and water quality (i.e., surface films or pH) which, in turn, may affect gas bladder inflation.

The fry samples provided a progression in age and size of fish, some collected before and others after feeding, with and without the yolk sac, and fish with and without gas bladder inflation, from a variety of experiments in which environmental variables differed substantially. MSU investigators found degenerative changes in the gas bladders (i.e., hyperplasia and abundance of macrophages) which were indicative of an inflammatory disease, and preliminary evidence to suggest a microbial infection as a specific initiating process. The observation of bacteria in the macrophages suggested a bacterial infection, at least as a secondary invader.

UCD investigators found that inflation of the swimbladder began on the 6th day posthatch, coinciding with the time of yolk sac depletion and initiation of feeding. In larvae with noninflated swimbladders, the pneumatic duct was obvious and its diameter remained fairly constant (25-45 µm) through the 19th day posthatch, but the pneumatic duct atrophied in larvae with inflated swimbladders. During the interval of swimbladder inflation, from the 6th to the 12th day posthatch, the common bile duct and pneumatic duct both opened to undifferentiated foregut where surfactant-like secretions from the common bile duct could affect fragmentation of large ingested air bubbles for transfer into the relative small-diameter pneumatic duct. After the 12th day posthatch, however, the pyloric sphincter developed and separated the common bile duct in the intestine from the pneumatic duct in the dorsal wall of the stomach. Thus, this finding indicates that differentiation of the foregut prevents inflation of larvae after 12th day posthatch. The day for these events, however, will vary depending on water temperature.

IMPACTS

OBJECTIVES 1 AND 2

These studies initially generated the basic knowledge of the reproductive cycle of walleye that was needed to begin efforts at controlling reproduction in walleye. This information was subsequently used to develop methods for inducing out-of-season spawning in walleye from late January through March.

The investigators also detailed techniques useful for synchronizing spawning in walleye, resulting in greater predictability of gamete production, and reduced incidence of failed spawning, gamete resorption and subsequent brood fish losses. These techniques can be used to increase hatchery efficiency and reliability.

Recently, UW-Madison personnel successfully led an effort to gain FDA-INAD approval to use hCG to induce spawning in walleye and yellow perch. This approval involves three regional private sector producers, and was done with the help of and in conjunction with the Iowa DNR.

Walleye producers (including the Iowa DNR) have used the technologies developed from these studies to produce walleye fry 9-12 weeks prior to the normal spawning season, and thereby greatly extended the period of time during which larval walleye can be reared intensively. This, in turn, has greatly increased the efficiency of existing intensive fry culture systems, facilitated research on the intensive culture of walleye fry, and aided hatcheries in their efforts to produce larger walleyes for stocking.

OBJECTIVE 3

Research on the use of zooplankton inoculation for pond culture of fish has not been systematically studied in walleye fingerling culture. In the present study, zooplankton inoculation of walleye culture ponds during the week walleye fry were first stocked reduced survival and yield. It was surprising to find lower survival and production in ponds supplemented with zooplankton because the method is believed to increase forage for fingerlings. However, basic studies by aquatic ecologists has long demonstrated the difficulties of precise prediction of zooplankton dynamics in ponds and lakes. Moreover, the use of zooplankton inoculation is an unproven method for biomanipulation of aquatic ecosystems, even as small as fish culture ponds. Zooplankton inoculation may be beneficial in ponds filled with water which is devoid of planktonic life (e.g., well water) but at hatcheries which fill ponds with surface water there may be no benefit of adding zooplankton and it may actually be detrimental to production.

These findings indicate that zooplankton inoculation as a pond management strategy must be undertaken with caution. It seems, however, that ponds should not be inoculated with large cladocera shortly after stocking walleye fry because seeding ponds with zooplankton that are too large to be eaten by first feeding walleye may encourage a competitive advantage for the larger zooplankton over the smaller cladocera and copepods that are essential prey for first feeding larval walleye. In this study, the organisms used for seeding were generally larger than 2 mm (0.08 in) which is larger than first feeding walleye (about 9 mm; 0.35 in) can consume. It has been reported by others that the mean length of zooplankters in gut contents of first feeding walleye was 1.1 mm (0.04 in) at one study site and 0.8 mm (0.03 in) at another study site.

OBJECTIVE 4

Basic studies on the ecology of clam shrimp in culture ponds demonstrate that strategies for control of clam shrimp in culture ponds need to consider both the life history characteristics of clam shrimp and fish cultural practices. Clam shrimp life history information provided insight into pond management strategies to reduce the impacts of clam shrimp on fish production. The typical habitat of most North American clam shrimp species is small, ephemeral ponds. The key to clam shrimp survival in this habitat is their ability to produce eggs that are highly resistant to drying, mechanical injury, and freezing. Clam shrimp problems in fish culture ponds are persistent because the resting eggs are resistant to mechanical injury, sunlight, and desiccation. Clam shrimp resting eggs can survive long periods of direct sunlight and wind, which they encounter when culture ponds are drained for harvest. Control measures for clam shrimp include interruption of the wet-dry cycle in fish culture ponds, a fill-drain-and-fill strategy, biological control, and chemical control. A fill-drain-and-fill strategy would involve partial pond filling in the spring long enough for clam shrimp eggs to hatch, then drained to flush out the newly hatched clam shrimp nauplii. The current tandem culture system at the GDNFH is a type of fill-and-drain strategy. At GDNFH, the northern pike culture season seems to end before clam shrimp reach sexual maturity, and many juvenile clam shrimp are flushed out before they were able to produce either summer or resting eggs. Also, many, but not all juveniles stranded on the pond bottom die before the ponds are refilled. These practices reduced the abundance of clam shrimp during the walleye culture season because clam shrimp that are hatched during the first week of northern pike season were unable to reproduce before they were washed out when the ponds were drained to harvest the northern pike. Although many of the clam shrimp were washed out, as observed in the catch basin when the ponds were drained, some clam shrimp are carried-over to the walleye culture season by surviving in the kettle and on the wet pond bottom. Although these clam shrimp would be killed with a longer drying period, it is not possible to delay refilling (mean of 1.6 d in 1992) because hatching of these walleye has already been delayed to facilitate the double-cropping strategy. Biological control of clam shrimp with a predaceous fish does not seem to be effective because neither northern pike nor walleye culture feed on clam shrimp. Chemical control may be possible. Quicklime (calcium oxide, CaO) or slaked lime (calcium hydroxide, $Ca(OH)_2$) is generally recognized as safe as a pond sterilant by FDA and can be applied at the rate of 1,500 kg/ha (1,338 lb/acre) as quick lime or 2,000 kg/ha (1,784 lb/acre) as slaked lime. Lime is often used as a pond disinfectant to kill infectious organisms and parasites, including fish, tadpoles, and insects. The toxicity of lime to clam shrimp resting eggs has not been evaluated, but it is a potential treatment for killing clam shrimp eggs if the lime is applied to the moist pond bottom after it is drained at the end of each production season. In a hatchery such as the GDNFH, the best time to make a lime application would follow the walleye harvest. Previously, trichlorfon (commercially sold as Masoten™ or Dylox™) was widely used for control of clam shrimp, but is not registered for use in fish culture ponds. Other studies show that trichlorfon treatment may be detrimental to zooplankton and invertebrates.

OBJECTIVE 5

Culture tanks equipped with a surface spray, using about 10% of the inflow directed through a 90° nozzle to the water surface, removed the oil film, and feed and bacterial growth from the tank surface, thereby greatly enhancing gas bladder inflation. Gas bladder inflation, which was 20-40% without a surface spray, was 80 to 100% with a spray. Circular tanks (cylindrical tanks) with black-painted side walls were found to be more effective culture vessels than cuboidal tanks or tanks with blue-colored side walls. A near neutral pH is a healthier environment for larval fish than one supplied with water with high pH (≥8.5).

Development of a successful intensive culture system is essential for use of out-of-season spawning of walleye when ponds are not available for stocking. The successful development of techniques for out-of-season spawning and intensive culture system for rearing larval walleye represent a major breakthrough in walleye culture, opening new opportunities of research and commercial culture.

RECOMMENDED FOLLOW-UP ACTIVITIES

OBJECTIVES 1 AND 2

Further efforts should be directed at developing techniques to induce out-of-season spawning in walleye throughout the year.

OBJECTIVE 3

The findings of negative effects from zooplankton inoculation suggest the need for further research to provide further explanation, and the need to define how and when (i.e., the timing) zooplankton inoculation may be used in pond culture of walleye. Distinction needs to be made between ponds receiving zooplankton from the water supply and those filled with well-water and devoid of zooplankton. Likewise, little attention has been given to measuring the quantity and impact of zooplankton inoculation from the water supply of fish hatcheries using surface water sources.

OBJECTIVE 4

Strategies for control of clam shrimp in culture ponds with quicklime (calcium oxide, CaO) or slaked lime (calcium hydroxide, $Ca(OH)_2$) need evaluation because these chemicals are approved for use in aquaculture.

OBJECTIVE 5

Noninflation of the gas bladder has been a major constraint to successful mass culture of walleye. The development of tank design and a spray-system to remove surface contaminants was a major breakthrough, however, survival is still typically less than 50% and further research would be beneficial to improve commercial feasibility. Research is especially needed on use of turbid water, optimizing light intensity, and feeding strategies for enhancing survival and growth of larval walleye.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED

See Appendix.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL[a]	OTHER[b]	TOTAL	
1989-91	$177,517	$127,535		$17,511		$145,046	$322,563
1991-92	$109,223	$73,242		$8,935		$82,177	$191,400
1992-93	$35,000	$26,475		$9,424	$40,990	$76,889	$111,889
TOTAL	$321,740	$227,252		$35,870	$40,990	$304,112	$625,852

[a]University of Wisconsin Sea Grant Program/USDC/NOAA

[b]Nebraska Game and Parks Commission

WALLEYE

Progress Report for the Period
September 1, 1993 to August 31, 1995

NCRAC FUNDING LEVEL: $150,000 (September 1, 1993 to August 31, 1995)

PARTICIPANTS:

Terence B. Barry	University of Wisconsin-Madison	Wisconsin
Tom Harder	Max McGraw Wildlife Foundation	Illinois
Anne R. Kapuscinski	University of Minnesota	Minnesota
Terrence B. Kayes	University of Nebraska-Lincoln	Nebraska
Jeffrey A. Malison	University of Wisconsin-Madison	Wisconsin
Robert C. Summerfelt	Iowa State University	Iowa
Extension Liaison:		
Ronald E. Kinnunen	Michigan State University	Michigan
Non-funded Collaborators:		
Gene P. Hanson	Aurora-Aqua, Inc., Kandiyohi	Minnesota
Iowa Department of Natural Resources (DNR)	Spirit Lake State Fish Hatchery	Iowa
Nebraska Game & Parks Commission	North Platte State Fish Hatchery	Nebraska
Nebraska Game & Parks Commission	Calamus State Fish Hatchery, Burwell	Nebraska
South Dakota Game, Fish & Parks Department	Pierre	South Dakota
Ohio DNR	Senecaville State Fish Hatchery	Ohio
U.S. Fish & Wildlife Service	Genoa National Fish Hatchery	Wisconsin
Wisconsin DNR	Lake Mills State Fish Hatchery	Wisconsin

PROJECT OBJECTIVES

(1) Measure genetic parameters required for efficient combined selection of sub-adult and adult traits, using a pedigreed population of walleye.

(2) Compare performance (survival, growth, feed conversion) of walleye hybrids produced from different parental stocks reared under intensive and the tandem extensive-intensive culture systems.

(3) Conduct field trials that compare effectiveness and costs of different pond and tank culture strategies for producing advanced fingerlings.

ANTICIPATED BENEFITS

The present study concerned problems identified by representatives of the aquaculture community in the North Central Region (NCR) as constraints to development and expansion of a commercial walleye food fish aquaculture industry. A major constraint to private aquaculture is the lack of domesticated brood stock, and biological and economic data on intensive and extensive methods for rearing of fingerlings. In addition, there is need for additional biological information on comparative performance of walleye and its hybrid, a cross between a female walleye and male sauger.

The focus of this project is on: (1) selective breeding based on family selection; (2) performance comparisons of purebred and hybrid walleye; and (3) field trials comparing the effectiveness and costs of different strategies for producing advanced fingerling walleye.

OBJECTIVE 1

The overall goal of this project is to overcome the biological constraints on the development and expansion of commercial walleye food fish aquaculture in the NCR. One major constraint is the lack of domesticated, selectively bred brood stock capable of spawning in captivity at age 3 years or younger. This study will complete the parent generation of work in development of a domesticated line selected for high performance in different indoor systems for food fish production. Benefits of improved performance of such a selected walleye strain will include reduced operating costs, harvest of a better quality product, and prevention of adverse environmental impacts.

OBJECTIVE 2

One primary constraint on the development and expansion of a commercial walleye food fish industry is the relatively slow growth of walleye when reared from advanced fingerlings to food size fish in intensive culture on formulated feed. Reasons for slow growth seem to have been attributed to early onset of sexual maturity of male fish, inadequate diets, and stressful rearing conditions. In typical tank culture conditions walleye are easily excitable, an attribute that may cause stress and contribute to their slow growth. Several studies have shown that juvenile walleye female × sauger male hybrids grow considerably faster and seem less agitated than purebred walleye when reared under typical intensive conditions. Additional studies are needed, however, to determine the extent to which the performance advantages of juvenile hybrid walleyes continue in fish reared to food-size, and to identify specific stocks of walleye and sauger that produce hybrid walleyes having the most desirable performance as measured by growth, feed conversion and disease resistance.

OBJECTIVE 3

Information on comparative costs of pond and tank culture strategies for producing advanced fingerlings has been lacking. Also, there is a need to transfer technology developed by NCRAC researchers and others for mass culture of larval walleye on formulated feed to others, and to determine the minimum size at which pond-reared walleye can be harvested and habituated (trained) to intensive culture conditions on formulated feed.

Economic analysis of alternative strategies for production of walleye fingerlings need to be obtained from field trials. The two methods are: (1) intensive walleye culture of fry to advanced fingerlings on formulated feed in tank culture, and (2) tandem culture whereby fry are first stocked in ponds, harvested as small fingerlings and transferred to tanks for habituation (training) to formulated feed and grow out to advanced size. An important consideration of the tandem culture process is a need to identify the minimum size at which pond-reared walleye can be harvested and habituated to intensive culture conditions and conventional diets that will allow producers to maximize the number of fingerlings that can be produced in ponds, thereby minimizing production costs. Development of in-pond habituation techniques will help control manpower costs during the habituation period and capital investments necessary for facilities in which to practice intensive fry culture and fingerling habituation.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1

Between September 1, 1994 and August 31, 1995, University of Minnesota (UM) investigators collected individual performance data on weight at different ages, length at different ages, specific growth rates, survival rate, and incidence of deformities for individual fish belonging to 12 full-sib families nested within four half-sib families and to a control group reared at UM wet laboratory and at Aurora Aqua, Inc., a commercial walleye aquaculture enterprise. This pedigreed population had been founded in May 1993 from gametes collected from a wild population. Juvenile fish were individually tagged, either with passive integrated transponder (PIT) tags or visible implant tags, to allow collection of individual performance records. Prior to this project period, UM investigators collected data on early life traits (cannibalism, oil globule diameter, gas bladder inflation rate, length at age, weight at age, and survival rate). For fish held at UM, investigators have estimated sire and dam heritabilities and standard errors of length and weight at 25 different ages (from 1 day to 375 days) and oil globule diameter. Heritability values can range from 0 to 1, and potential response to selection increases as heritability increases. Examples of some of the traits with heritabilities sufficiently high that selective breeding should show a good response in the next generation are: heritability of 0.41 for 47 day weight, and 0.93 for 247 day weight. For instance, artificial crosses between adults who had high weight when they were 47 days old would yield progeny with increased weight at 47 days. In fall 1995, using nonsponsored funds, UM investigators began exposing fish to ambient photoperiod and temperature in order to stimulate onset of gonadal development and maturation. This should yield some sexually mature adults for selective breeding in spring 1996 but funding for this project was terminated on August 31, 1995.

OBJECTIVE 2

Iowa State University (ISU) and University of Wisconsin-Madison (UW-Madison) investigators collaborated to make comparisons of pure stock walleye with hybrid walleyes (male sauger × female walleye). In 1994, hybrids were produced from three stocks of female walleye and a single stock of sauger, and in 1995 hybrids were produced from a single stock of walleye and three stocks of sauger. The wild brood stock was obtained with the assistance of state and federal agencies. ISU researchers collected eggs and prepared extended semen. They made the crosses and reared the fish in intensive culture on formulated feed to at least 75 mm. At that time, fingerlings were transported to the Lake Mills State Fish Hatchery, Lake Mills, Wisconsin where UW-Madison researchers have been rearing the fish to food size.

The 1994 year class consisted of three groups of hybrid walleye made by crossing male sauger collected from the Mississippi River near Genoa, Wisconsin with female walleye collected from the same source (Genoa hybrids, GH), Spirit Lake, Iowa (Spirit Lake hybrids, SLH), and Rock Lake, Wisconsin (Rock Lake hybrids, RLH). A control group of pure stock walleye was prepared from Rock Lake walleye (RLW).

In both 1994 and 1995, the length at hatching of pure stock walleye was greater than that of any of the hybrid groups. In both 1994 and 1995, hybrid walleye were longer than pure stock walleye by 28-30 days. In 1994, at 30-days, differences in survival among the four groups was not significant, but there was a significant difference in total length (TL) and weight; the three hybrid groups were significantly larger than that of the pure stock walleye (RLW). At both 30-days and 74-days, the SLH were longer and heavier than the two other hybrids and the pure stock walleye. At 74-days, the four groups of fish were transported to the Lake Mills State Fish Hatchery for further rearing by investigators from UW-Madison. The average TL of all tank-reared fingerlings that were transported was 86 mm (3.4 in).

The 1995 year class of hybrids was produced by crossing female Spirit Lake walleye with extended semen of saugers collected from the Ohio River (ORH), Mississippi River (MIH), and Missouri River (MOH). Based on the results from 1994 at ISU and UW-Madison, female Spirit Lake walleye were used to make the 1995 year class. In 1995, when fry were 28-days old, the MOH were longer than any other group, but by 83-days, the MIH and ORH were similar in size, but both were longer and heavier than the Missouri River hybrids. The MIH were 15.7 mm (0.62 in) longer than the pure stock walleye (RLW).

In both 1994 and 1995, most, although not all, hybrid crosses grew faster than the parental stock through the first 74-83 days posthatch. The source of the parental stock is important. In both years, hybrids produced by crossing Spirit Lake walleye and Mississippi River sauger grew faster through the first 74-83 days posthatch than any other hybrid cross. Further grow out of these fingerlings to food size was carried out at UW-Madison.

In the last project year, UW-Madison investigators cultured the four groups of the 1994 year class. The growth phase with the 1994 year class will soon be completed as many of these fish were reaching market size. Throughout the grow out studies with the 1994 year class, all groups of hybrids grew faster than the purebreds, but growth of the SLH from 1994 was faster than the other hybrid groups. The SLH from the 1994 cohort are currently twice as large as the purebred walleye from Rock Lake, Wisconsin. In August, 1995 UW-Madison researchers received the four groups of fingerlings from ISU, the SLW and three groups of hybrids (ORH, MIH, MOH). An additional purebred (Rock Lake) walleye was added to obtain a comparison between the two years and to further delineate performance differences between geographic stocks of purebred walleye. The five groups of the 1995 cohort will be raised for another year as a component of the NCRAC walleye project that will begin September 1, 1995.

OBJECTIVE 3

Field trials were conducted at sites in northern Illinois (Max McGraw Wildlife Foundation), south-central Wisconsin (Lake Mills State Fish Hatchery), and western Nebraska (North Platte State Fish Hatchery).

Field trials at the Max McGraw Foundation were undertaken to demonstrate transfer of the intensive fry rearing technology developed jointly by ISU and the Iowa DNR Rathbun State Fish Hatchery, and to obtain comparative production costs for intensive (tank) and pond-culture methods to produce 30-day-old and advanced (150 mm; 5.91 in) fingerling walleye.

In 1994, a commercial-scale facility was developed at the Max McGraw Foundation for rearing walleye from fry to 30-days. The culture system was single-pass (i.e., not reuse or recycle), with three 650-L (171.7-gal), and three 1,200-L (317.0-gal) tanks. Fry were fed only formulated feed. The same facilities were used in both 1994 and 1995 culture seasons. In both years, fry were stocked at a density of 20 fry/L (76 fry/gal), and fed every 5 minutes, 22 hours a day. Although the culture techniques were successful in getting fry on feed and inflating their gas bladder, disease problems resulted in a near total loss of fish before 30-days. In 1994 the problem was an outbreak of bacterial gill disease when fry were 17-20 days posthatch which caused nearly 100% mortality. In 1995, two disease problems developed. The first was manifested one day after stocking. It was characterized by the presence of large gas bubbles in the abdominal cavity and fish swimming upside down. When fish were 22-days old, mortalities increased again, with many floating fish, fish with unusually shaped gas bladders, and fish with deformed vertebral column. The mean length of fish that survived to 49-days was 32.2 mm (1.27 in) TL, similar to mean lengths of 29.6 and 31.5 mm (1.17 and 1.24 in) for two groups of pond-reared fingerlings of about the same age. The disease problems in both years prevented accomplishment of the goal of comparing production costs for tank- and pond-culture methods. In spite of the problems, technology transfer seems to have been successful, inasmuch as the disease problems cannot be attributed to the culture system and the fact that fish accepted the feed and gas bladder inflation was accomplished. The disease outbreaks require further clarification as to etiology and research is needed to address these problems as well as feed quality. At this state in the development of technology for intensive culture, it may seem that tank culture presents the investor more risk than pond culture for obtaining a 30 mm (1.18 in) fingerling, however, it is also true that total pond failures occur from oxygen depletion, insect predation, starvation, and other problems. The variability in success of pond culture has long been recognized. For example, University of Nebraska-Lincoln (UNL) investigators reported that extremely cold weather in Nebraska in 1995 resulted in catastrophic losses of walleye fry in production ponds statewide.

In both 1994 and 1995, concurrent to tank culture, two ponds were used at the McGraw Foundation for a tandem pond-tank culture procedure to raise advanced fingerlings. Total harvest from the two ponds averaged 23% in 1994 and 14.4% in 1995 of the number stocked. Harvest was accomplished using a night-light technique to attract the fish, followed by drawdown, and further seining. In 1994, 41% of the fingerlings were harvested with the night-light technique, but in 1995, with additional experience and some improvements in the technique, more than 80% of the fingerlings that were harvested were captured by night-lighting. The poor survival was attributed to an abundance of tadpoles and tiger salamander larvae, and cannibalism.

In both years of the field studies at McGraw Foundation, a portion of the pond-reared fingerlings were transferred to tanks in the hatchery building for training to formulated feed and then for rearing to a target size of 150 mm (5.91 in). Two experimental conditions were studied, tank size (625- and

1,133-L; 165.1-299.3-gal) and tank color (light blue and black painted tanks). Survival to harvest averaged 22.5% (1994) to 28.2% (1995) of the number of fingerlings that were stocked in the tanks. In 1994, at harvest, 60.5% of the fish in the 625-L (165.1-gal) tanks were ≥150 mm (5.91 in), but only 38.6% of the stock in 1,133-L (299.3-gal) tanks were as large or larger than the target size. In 1995, the percentage of fish meeting the target size was less than in 1994; only 16.2% were ≥150 mm (5.91 in) in the small tanks and 13.5% in the large tanks. A major finding was the effect of tank color. In both years, food conversion (FC) was lower, growth faster, and percentage of fingerlings that reached the 150-mm (5.91-in) target size greater for fish raised in black tanks than fish raised in blue tanks. For both years combined, 46.8% of fish raised in black tanks were ≥150 mm (5.91 in) but only 13.5% of fish reared in blue tanks; FC was 1.3 in black tanks and 1.5 in blue tanks; and growth rates (mm/day) were 1.3 in black tanks and 1.2 in blue tanks. In 1995, expenses to produce fingerlings by the tandem production method using all variable costs (labor, feed, chemicals, fertilizer, pumping costs) averaged $0.42 for 127.8 mm (5.03 in) fingerlings reared in blue tanks and $0.46 for 140.5 mm (5.53 in) fingerlings reared in black tanks.

In 1994, investigators at UNL reported the findings of their studies on aeration, fertilization, and fry stocking density in ponds at the North Platte State Fish Hatchery, North Platte, Nebraska. Their 1995 studies were focused on developing and testing various large-scale low-stress harvesting systems to capture small walleye fingerlings (20-35 mm TL; 0.79-1.38 in) from heavily stocked production ponds (400,000 fry/ha; 161,880 fry/acre). The systems tested employed lights arranged (below and/or above the water surface) and operated (using dimmer switches) in a variety of ways to attract fish into specially designed passive-capture gear (i.e., two types of modified, open-topped fyke nets). Preliminary studies in 1994 revealed that one such system was capable of capturing 20,000-60,000 fingerlings of 20-30 mm (0.79-1.18 in) TL in a 15-20 min interval, repeatedly.

The purpose of the 1995 harvesting trials by UNL investigators was to verify the 1994 findings and compare different geometries of harvesting systems. Unfortunately, spring and early summer weather in Nebraska in 1995 was extremely cold and resulted in catastrophic losses of walleye fry in production ponds statewide. Consequently, the numbers of fish harvested per 15-20 min trial run were significantly lower (1,210-31,900 fish) than in 1994, and highly variable from run to run with each of the systems tested. However, sufficient numbers of trials comparing the various systems were run that we ultimately concluded that the geometries of the different systems tested had little significant effect on the numbers of fish captured and that, accordingly, under commercial conditions, operators should employ the system that is least expensive to build and operate.

As a consequence of the catastrophic losses of walleye fry and subsequent stocking needs of Nebraska Game and Parks Commission, a field trial to compare the merits of rearing small walleye fingerlings to advanced-fingerling size intensively in tanks versus extensively in ponds was not practicable. Only a small number of pond-reared advanced-fingerling walleye were produced. Comparative studies of the two methods of production may be possible in 1996 as part of the new Walleye Work Group project that will begin September 1, 1995.

Results from the 1994 and 1995 field trials at UW-Madison indicate that walleyes harvested from ponds at sizes 25-30 mm (0.98-1.18 in) TL can be habituated to intensive culture conditions and formulated feeds more successfully than those at smaller sizes. Equally as important, however, are our observations that significant variations occurred in the habituation of similar-sized fingerlings originating from different ponds. These variations did not result from any single factor. Taken together, these findings suggest that pond-reared walleye must reach a minimum size of 25-30 mm (0.98-1.18 in) TL to readily accept conventional starter feeds. Other variables, however, including size uniformity, condition, and pond water temperature, dissolved oxygen concentration and zooplankton density, have a great impact on the successful feed-training of pond-reared fingerlings in tanks. The degree of stress to which the fish are exposed during harvest also has a major impact in this regard.

WORK PLANNED

OBJECTIVE 1

For fish held at Aurora Aqua, Inc. estimation of heritabilities for early life traits will be completed. For all fish, investigators will estimate heritabilities of additional traits (length and weight at different ages >375 days, specific growth rate for weight at different age intervals, incidence of cannibalism, gas bladder inflation) and genetic correlations between different combinations of traits. Results will appear in a completion report for NCRAC and a paper submitted to a peer-reviewed journal. These estimates of heritabilities and genetic correlations are needed to design an optimum selection scheme for the first set of artificial matings.

OBJECTIVE 2

Research at ISU under this objective was completed with the transfer of the four groups of the 1995 year class to investigators at UW-Madison. Findings from 1994 and 1995 will be prepared for publication in appropriate scientific journals. UW-Madison investigators will continue to collect performance data on the four groups of walleye produced in 1995 that are currently being raised to food size. Performance studies of the 1994 purebred and hybrid walleyes will conclude in the fall of 1995, and subsequent organoleptic comparisons and proximate analyses will be conducted. Performance data will be collected on the 1995 purebred and hybrid walleye until the autumn of 1996, at which time these fish will also be subject to organoleptic comparisons and proximate analyses.

OBJECTIVE 3

Field trials at the McGraw Foundation were completed in August 1995. Findings will be prepared for publication or communication at appropriate aquaculture meetings. No further work is planned by UW-Madison researchers under this objective.

The "hands-on" components of the research proposed by UNL investigators under this objective for the most part have been completed, as has much of the biological data analysis. Presentations on findings to date have been given at a scientific and an extension meeting, and more will be given in the months ahead. A Master’s thesis and a major manuscript on the production of walleye fingerlings at high densities in ponds are close to completion, and the latter will be submitted for publication to a peer-reviewed journal. After that, a manuscript on large-scale low-stress methods of harvesting small walleye fingerlings using light will be similarly submitted for publication. Immediately following acceptance of these manuscripts by scientific journals, the commercially applicable aspects of the UNL findings will be disseminated via extension publications and videotapes, as future funding allows.

By April 1996, compilations of the estimated *direct* costs of the high-density culture of walleye fingerlings in ponds should be completed and will be turned over to NCRAC Economics and Marketing Work Group members for more in-depth analyses of production costs. Significantly, most aspects of the research conducted on this objective by UNL investigators will be continued as an intrinsic part of Objective 1 of the new NCRAC Walleye Work Group project for FY 1995-97 titled "Advancement of and a Market Study for Walleye Aquaculture." Objective 3 of the same new project provides a mechanism for developing and disseminating extension materials on recently established research findings, including those on new pond production and harvesting procedures.

IMPACTS

OBJECTIVE 1

UM investigators have produced major elements of a walleye selective breeding program, established a pedigreed captive population, and estimated genetic parameters for performance traits under indoor rearing conditions in both laboratory and production facilities. Selection programs in salmonids have improved the performance of desirable traits for aquaculture by as much as 14-30% per generation. Selective breeding programs developed for indoor food-fish aquaculture of walleye should lower operating costs, improve consistency of yields and improve the final product. Aurora Aqua, Inc., a private sector cooperator and a leader in walleye culture, has been learning how to undertake a selective breeding program.

OBJECTIVE 2

This research will benefit producers because it demonstrates that hybrid walleye have superior performance traits to purebred walleye when raised to food size. Also, the findings indicate that the parental stock used to prepare hybrids makes a major difference in the performance traits of the hybrid. Identification of specific hybrid crosses having superior growth rates and performance traits will substantially reduce the time needed to rear these fish to market size, and thereby reduce the costs required to produce food-size fish. Results to date suggest that the time needed to rear certain hybrid walleye to market size might be 50% or less than that required for purebred walleye.

OBJECTIVE 3

Technology transfer of the ISU-Rathbun techniques for intensive culture of walleye fry was demonstrated at the McGraw Foundation site. Use of turbid water prevented fry from clinging to tank walls, the fry accepted the formulated feed readily, and the spray bar technique was effective for obtaining gas bladder inflation in walleye. However, disease problems, bacterial gill disease in 1994, and a type of gas bubble disease and vitamin deficiency in 1995, caused a total loss of fish before 30-days in 1994 and poor results in 1995. Field trials for the tandem pond-tank procedures for training pond-reared walleye were completed. They provided information on use of the night-lighting technique for harvesting 30-mm (1.18-in) fingerlings and they demonstrated substantial benefits from using black rather than blue tanks. Production costs for rearing advanced fingerlings are documented.

The average estimated number of 25-50 mm (0.98-1.97 in) TL walleye fingerlings produced per annum by the Nebraska Game and Parks Commission at the North Platte State Fish Hatchery and statewide for the 3-year period 1990-1992 was over 1.3 million/year (the North Platte Hatchery was essentially the state's sole producer of walleye fingerlings). In 1994, the estimated numbers of these size fish at the North Platte Hatchery and statewide were 3.4 and 4.3 million, respectively. The over two-fold increase in production at the North Platte Hatchery was directly attributable to UNL's research efforts there. Of the statewide overall increase in walleye fingerling production in 1994, compared with the 1990-1992 average, about 71% was attributable to UNL's research at the North Platte Hatchery while the remaining 29% was due to production at the Calamus State Fish Hatchery.

In summary, the research done by UNL investigators has demonstrated that walleye fingerlings can be produced on a commercial scale in ponds at three times the densities traditionally employed, with no significant loss in survival and only a small reduction in size at harvest. In addition, large-scale low-stress methods have been developed for harvesting small walleye fingerlings at a size at which they can be readily habituated to conventional starter trout or salmon diets. These new developments, in tandem with the findings of UW-Madison investigators, provide a highly efficient, low-cost means of producing walleye fingerlings that are trained to formulated feed using already available pond facilities across the NCR.

UW-Madison investigators have generated much needed information on optimizing the tandem pond/tank method for raising fingerling walleye habituated to formulated feed, and this information will be useful to further delineate production costs for this method.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED

See Appendix.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1993-94	$72,725	$111,029	$11,250[a]	$11,000[b]	$57,420[c]	$190,699	$263,424
1994-95	$77,275	$44,773	$13,080[a]	$11,000[b]	$32,350[d]	$101,203	$178,478
TOTAL	$150,000	$155,802	$24,330	$22,000	$89,770	$291,902	$441,902

[a]Aurora Aqua, Inc.

[b]Wisconsin Sea Grant/USDC/NOAA

[c]1993-94: Max McGraw Wildlife Foundation ($14,900), Minnesota Department of Natural Resources ($820), Nebraska Game and Parks Department ($41,700)

[d]1994-95: Max McGraw Wildlife Foundation ($14,900) and Nebraska Game and Parks Department ($17,450)

SUNFISH

Project Component Termination Report for the Period
June 1, 1990 to August 31, 1995

NCRAC FUNDING LEVEL: $280,625 (June 1, 1990 to August 31, 1994)

PARTICIPANTS:

Donald L. Garling	Michigan State University	Michigan
Robert J. Sheehan	Southern Illinois University-Carbondale	Illinois
Bruce L. Tetzlaff	Southern Illinois University-Carbondale	Illinois
Extension Liaison:		
Joseph E. Morris	Iowa State University	Iowa

REASONS FOR TERMINATION

Objectives completed and funding terminated.

PROJECT OBJECTIVES

(1) Determine the mechanisms of sex control in sunfish and to produce and evaluate polyploid sunfish and hybrids.

(2) Determine optimal stocking densities and relationships between temperature and growth for *Lepomis*, *Lepomis* hybrids, and triploid *Lepomis*.

PRINCIPAL ACCOMPLISHMENTS

An evaluation of both cold and pressure shocks of varying magnitudes, initiation times (time after mixing egg and sperm), and durations to determine the optimum treatments to produce tetraploid (organisms with twice the number of normal chromosomes) bluegill (*Lepomis macrochirus*) has been completed at Michigan State University (MSU). Tetraploidy was induced in five of the 16 cold shock treatments tested. Maximum induction rates of 40% are comparable to those achieved in other species. Of the 10 pressure treatments examined, none were successful in producing tetraploids. Relative survival ranged from <1 to 34% for bluegill exposed to cold shock treatments or pressure shock treatments, respectively.

Twenty-seven combinations of pressure (41,369, 48,264, or 55,158 kPa), shock durations (2, 3, or 4 min), and post-fertilization shock initiation times (2, 3, or 4 min) were tested at Southern Illinois University-Carbondale (SIU-C) to identify treatments which would most efficiently induce triploidy in green sunfish (*L. cyanellus*) male × bluegill female F_1 hybrids. Several of the shock treatments produced 100% triploids with at least 90% survival relative to controls. The two shock treatments which appeared to be most effective were: (1) 48,265 kPa for 4 min begun 2 min postfertilization; and (2) 41,369 kPa for 2 min begun 3 min postfertilization. A paper based on this work appeared in the *Journal of the World Aquaculture Society*; it is the first publication on shock-induced triploidy in *Lepomis*.

Using starch gel electrophoresis, a diagnostic genetic technique, SIU-C investigators found that they could distinguish among three species of sunfish: bluegill, green sunfish, and pumpkinseed (*L. gibbosus*). Furthermore, use of this technique made it possible to identify hybrids of these species;

however, it did not allow for the identification of triploids.
Bluegill had a lower mean weight and poorer food conversion after 121 d of growth in a trial comparing bluegill, green sunfish, and male bluegill × female green hybrids. No significant differences were found between green sunfish and hybrids for final weight, specific growth rate, percent weight gain, or food conversion. Growth occurred over the entire range of temperatures tested, 8 to 28°C (46-82°F) at 5°C intervals; 23°C (73°F) was optimum.

Male bluegill × green sunfish female triploid and diploid F_1 hybrid growth performance was compared in a 230 d trial at 23 °C (73 °F). Diploids showed larger final weight and better specific growth rate, percent weight gain and food conversion.

In a third growth trial at SIU-C, diploid male bluegill × female green sunfish F_1 hybrids and green sunfish were compared to triploid male green sunfish × female bluegill F_1 hybrids over 235 d. Diploid taxa were selected on the basis of the results of the 121-d growth trial. No significant differences in weight, specific growth rate, percent weight gain or food conversion were found. Green sunfish had lower dress out weights than either hybrid. Gonadal somatic index was higher in the green sunfish than in the diploid and triploid hybrids. The vast majority of the green sunfish became sexually mature and were producing gametes over the range of tested temperatures, 8-28°C (46-82°F). Growth occurred at all temperatures; 18°C (64°F) was optimum. Lower growth rates and reduced optimum temperature were attributed in this trial to the use of fish larger than the ones used in the all-diploid growth trial.

Given the presumption of sterility and other potential advantages, triploids are a viable alternative for intensive food fish culture; they will not reproduce in culture units and will not cause genetic contamination of wild stocks. Male green sunfish × female bluegill F_1 hybrid triploids and male bluegill × female green sunfish diploid F_1 hybrids performed similarly in growth trials at SIU-C and appeared to be the best candidates for food fish production.

The pressure-induced triploidy and allozyme species identification techniques derived at SIU-C were used to produce gynogens (an organism with only maternal chromosomes) in a study to investigate the genetic sex determination system in bluegill. Heterologous (green sunfish) spermatozoa were irradiated, 15-360 sec, with 1500 uW/cm^2 of 254 nm wavelength UV light to deactivate the DNA. The irradiated spermatozoa were then used to activate bluegill eggs.

Control eggs which were not shocked but activated with irradiated sperm were all (N = 37) haploid; controls which were fertilized with normal spermatozoa and not shocked were all diploid (N = 21). Sperm irradiation times of 120, 150, or 180 sec plus the hydrostatic shock produced 48 diploids (gynogens) and no individuals with other ploidy levels or green sunfish loci, indicating 100% gynogen production efficiency.

Supposed gynogen larvae (N = 150) were then produced and stocked into a pond. Seven sexually mature gynogens were recovered from the pond. All seven were pure bluegill, based on allozyme analysis, and female. The probability of obtaining seven females from a 1:1 sex ratio population is only 0.008. This is strong evidence that the female is the homogametic sex and that an XX/XY genetic sex determination system occurs in bluegill.

This is the first study reporting induced gynogenesis and gynogen sex ratios in bluegills; this provides the foundation necessary for developing a technique for all-female production in bluegill. Sex reversal of gynogens would yield phenotypic males that would produce all-female progeny when crossed with normal females. This strategy could be used to eliminate reproduction in bluegill culture units, developing techniques for eliminating reproduction is one of the more important goals of the NCRAC sunfish research effort.

Stocking densities for sunfish in cages and ponds were also evaluated at SIU-C. Hybrid sunfish (bluegill male × green sunfish female) grew better at densities of 100 (3 fish/ft^3) and 200 fish/m^3 (6 fish/ft^3) than at 400 fish/m^3 (11 fish/ft^3) in cages. Food conversion was best at the lowest density and it became worse as density was increased.

Growth of hybrid sunfish was directly related to stocking density in ponds at the tested densities of 7,410, 4,940, and 2,470 fish/ha (3,000, 2,000, and 1,000 fish/acre). Food conversion also improved as density increased in ponds. Food conversion (weight of food fed/weight gain) ranged from 2.5 to 5.3 in the highest and lowest density ponds, respectively.

IMPACTS

Control of Sunfish Reproduction

The development of protocols for reducing reproduction in these fishes allows for the potential of increased growth of these fish in aquaculture systems as opposed to unrestrained reproduction. The two shock treatments which appeared to be most effective were: (1) 48,265 kPa for 4 min begun 2 min post-fertilization; and (2) 41,369 kPa for 2 min begun 3 min post-fertilization.

Optimal Stocking Densities

Information garnered from this work indicates the desirabilities of these fish for aquaculture in the North Central Region. The sunfish species and diploid and triploid hybrids which were evaluated showed optimum growth at temperatures of 18 to 23°C (64-73°F); all groups grew across a temperature range of 8 to 28°C (46-82°F). Even at 8°C (46°F), the sunfish species, diploid and triploid hybrids, were evaluated showed 150 to 200% weight gains over 121 d, and growth rates generally increased with increasing temperature. In light of results from this research project, the male bluegill × female green sunfish diploid F_1 hybrid and the male green sunfish × bluegill sunfish triploid F_1 hybrid appeared to be the best candidates for aquacultural production.

A stocking rate of 200 fish/m^3 (6 fish/ft^3) is the recommended stocking density for sunfish in cages. In open pond culture, the recommended stocking density for sunfish is 12,355 to 17,297 fingerlings/ha (5,000 to 7,000 fingerlings/acre).

RECOMMENDED FOLLOW-UP ACTIVITIES

The male green sunfish × female bluegill triploid hybrid grew as well or better than the other four *Lepomis* taxa (green sunfish, bluegill, male bluegill male × female green sunfish hybrid and male bluegill × female green sunfish triploid hybrid) evaluated. There is a need to evaluate growth in this triploid to a larger size, because triploids, theoretically, have their greatest growth advantage over diploids after the diploids reach sexual maturity.

One of the major impediments to open pond culture of sunfish is uncontrolled reproduction. Monosex sunfish production would eliminate this problem. An important first step has been taken in the development of monosex stock production in sunfish. Induced gynogenesis in bluegill has been accomplished at SIU-C. The mating of sex-reversed XX gynogens to normal XX females would produce all-female progeny. Although females did not grow as well as males in SIU-C's studies, their growth performance could be considerably enhanced in the absence of males. There is a need to explore monosex stock production in sunfish to determine if this is a viable means for controlling reproduction in culture units.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED

See Appendix.

TOTAL PROJECT SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1990-92	$130,758	$96,710				$96,710	$227,468
1992-94	$149,867	$313,330	$3,200[a]		$29,830[b]	$346,360	$496,227
TOTAL	$280,625	$410,040	$3,200		$29,830	$443,070	$723,695

[a]American Fishing Tackle Manufacturing Association
[b]Illinois Natural History Survey

SUNFISH

Progress Report for the Period
June 1, 1990 to August 31, 1995

NCRAC FUNDING LEVEL: $455,624 (June 1, 1990 to August 31, 1996)

PARTICIPANTS:

Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin
Paul B. Brown	Purdue University	Indiana
Donald L. Garling	Michigan State University	Michigan
Robert S. Hayward	University of Missouri-Columbia	Missouri
Michael L. Hooe	Illinois Natural History Survey	Illinois
Terrence B. Kayes	University of Nebraska-Lincoln	Nebraska
Christopher C. Kohler	Southern Illinois University-Carbondale	Illinois
Joseph E. Morris	Iowa State University	Iowa
Douglas B. Noltie	University of Missouri-Columbia	Missouri
Robert J. Sheehan	Southern Illinois University-Carbondale	Illinois
Bruce L. Tetzlaff	Southern Illinois University-Carbondale	Illinois
James R. Triplett	Pittsburg State University	Kansas
David H. Wahl	Illinois Natural History Survey	Illinois
Extension Liaison:		
Joseph E. Morris	Iowa State University	Iowa
Non-Funded Collaborators:		
Denzil Hughes	Farmland Industries, Inc.	Kansas
Illinois Department of Conservation	Little Grassy Fish Hatchery, Carbondale	Illinois
Jim Frey	Jim Frey Fish Hatchery, West Union	Iowa
Ron Johnson	Spruce Creek Fish Farm	Minnesota
Myron Kloubec	Kloubec Fish Farms, Amana	Iowa
Missouri Department of Conservation		Missouri
Tribal Council	Red Lake Band Chippewa	Wisconsin
National Biological Service	Midwest Science Center (formerly USFWS National Fisheries Contaminant Research Laboratory)	Missouri

PROJECT OBJECTIVES

(1) Determine optimum stocking densities and relationships between temperature and growth for crappie, crappie hybrids, and triploid crappie.

(2) Produce a production manual, accompanying videos and other information as necessary to demonstrate the technology for culturing centrarchids.

(3) Determine the major nutritional requirements for centrarchids and to compare their growth and performance

using available commercial feeds in laboratory and field settings.

(4) Determine the best feeding management strategies for culturing centrarchids in laboratory and field settings.

ANTICIPATED BENEFITS

Studies are currently underway to determine which of the sunfishes, such as bluegill, green sunfish, black and white crappie, sunfish hybrids, and/or triploids, are most suitable for aquacultural production in the region. Survival, growth rate and efficiency, growth performance in relation to temperature, and tolerance to crowding were used to determine best performance by a taxa.

Significant progress has been made with regard to sunfish brood stock development, spawning, acceptance of prepared diets and good growth response. Most of the research and commercial production of sunfish has focused on utilizing pond systems (extensive aquaculture). However, to a lesser extent this same effort has been directed at intensive aquaculture. With a better understanding of the early life stage feeding strategies the aquaculture industry will be able to broaden the scope of sunfish aquaculture to include rearing these fish under intensive conditions.

At the 1993 Program Planning Meeting held in Madison, Wisconsin, the NCRAC Industry Advisory Council (IAC) specifically requested the development of extension educational materials in the form of a production manual and accompanying video tapes, as a high priority need for demonstrating the commercial feasibility of centrarchid sunfish aquaculture in the region. Such information is needed to enable this industry to enlarge.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

Objectives related to production of polyploid sunfish, and stocking densities and growth of *Lepomis* species have been completed. Refer to the associated termination report for information regarding completed objectives in this project.

Pure stock white, diploid F_1 hybrid and triploid F_1 hybrid crappies were produced at the Sam Parr Biological Station by Illinois Natural History Survey (INHS) personnel during spring 1994, with assistance from Southern Illinois University-Carbondale (SIU-C) researchers. To produce F_1 crappie fry, eggs from ripe female crappies were fertilized *in vitro* and incubated in recirculating systems in Heath™ spawning trays modified with 52 × 52-twill saran cloth screens at 21°C (70°F) . Half-sibling diploid hybrid and white crappies were produced by dividing the eggs from each female white crappie into two groups of approximately equal numbers and fertilizing half with sperm from a white crappie and half with sperm from a black crappie. Triploid F_1 hybrid crappies were produced by pressure shock.

Hatching occurred 36 - 48 h postfertilization for all three genetic stocks. Fry were removed from spawning trays 5 d posthatch, counted into transport containers and then stocked into 0.4 ha (1.0 acre) grow-out ponds. In spring 1994, ponds were drained and hybrid, pure stock white and pure stock black crappies (85 - 100 mm total length [TL]; 3.3 - 3.9 in) were transported to Pittsburg State University (PSU), (*N* = 1,300-1,500 of each stock) and to SIU-C (*N* = 400-500 of each stock).

The research from PSU indicates the following observations:

- Capture and post-transport mortalities were very high, but a small percent of the wild caught white crappie (2%) from the summer of 1993 survived and showed significant growth. These fish were moved indoors for further feeding trials in a recirculating system.

- Optimum stocking densities were not adequately determined for white crappie. In all cases (from 1.8 to 5.0 kg/m^3 [0.1-0.3 lb/ft^3]) overall survivability in cages was poor. However, survival was high and growth was acceptable in indoor trials at densities of 4-5 kg/m^3 (0.2-0.3 lb/ft^3).
- The high mortalities (57-98%) related to capture and transport of wild caught white crappie during 1993 were reduced to 0% in 1994. Approximately 4,200 fish were transported from the Sam Parr Biological Station in Illinois to the PSU Research Reserve in Kansas in two hauls of eight h (702 km [436 mi]) each, without any mortalities. The fish were handled and transported at night with temperatures less than 20°C (68°F) at 4-6 mg/L DO using oxygen diffusers and water treatments of 0.5% salt, PolyAqua™ (0.175-0.375 mL/L), and AmQuel™ (0.125 mL/L). Prior to handling for measurements, fish were anesthetized in Finquel™.
- White crappie, which were wild caught and fed in cages through the summer of 1993, were moved indoors in November and kept in two tanks in a recirculating system at a density of 4-5 kg/m^3 (0.2-0.3 lb/ft^3) for nearly 18 months. During the six feeding trials, only 17 of the 71 fish died, and 16 of these were killed by a single high chlorine event that resulted from a malfunction of the make-up water system.
- Black crappie out-performed both white crappie and hybrid crappie in the second year of the cage culture trials. Black crappies showed the greatest growth rates, feed acceptance, uniformity, and survivability, with white crappies intermediate, and hybrid crappie showing poorest overall performance.
- Fish consumed and grew on 2.5 mm (0.1 in) Biodiet™ pellets in both cage trials and recirculating system trials. Examination of the abdominal cavity in all cases revealed fatty livers and the cavity packed with fat.
- Observations of feeding activity in recirculating tanks suggested the formation of feeding hierarchies. Separate feeding experiments in aquaria during the summer of 1994 as part of a National Science Foundation (NSF) research training academy confirmed the presence of a dominance hierarchy.

Two growth trials were completed at SIU-C. The first trial examined black crappie (BC), white crappie (WC), male black crappie × female white crappie F_1 hybrids (BC × WC) and triploid white crappie. In the second trial, black crappie, BC × WC hybrids and male bluegill (BG) × female green sunfish (GS) F_1 hybrids (BG × GS) were examined. Growth was evaluated at five temperatures, across a range of 10 to 26°C (50-79°F) in both trials.

It was difficult to get all three crappie taxa to accept prepared feeds. Thus, a training period of two months was used prior to initiating the first growth trial. Training consisted of offering 3-mm (0.1-in) Biodiet Grower™ sinking feed pellets to the fingerlings continuously via automatic feeders. The feeding response from the crappie was modest at best. This contrasted markedly with *Lepomis* taxa, which have all readily accepted this feed, as well as floating feeds in prior studies at SIU-C.

Growth was extremely poor for all three

crappie taxa in the first trial. The response to the feed remained poor throughout the study, and the poor growth was attributed to low feed consumption. None of the taxa accepted feed at rates more than 1 to 1.5% of their body weight per day.

Although the white crappie grew about as well as the other two crappie taxa in the first trial, they were not used in the second trial. The black crappie and the BC × WC hybrid were compared to the BG × GS hybrid in the second trial because they showed greater disease resistance and better survival, generally, compared to the white crappie. The black crappie and the hybrid crappies used in this study had been reared in tanks for nearly one year. Consequently, their acceptance of prepared feeds was somewhat better in the second trial.

Growth of the *Lepomis* hybrid (BG × GS) was better than *Pomoxis* hybrid (BC × WC) or the black crappie. Growth of the BG × GS hybrid was consistent with SIU-C researchers' previous studies with *Lepomis*; best growth was obtained at 18 to 22°C (64 to 72°F), yet substantial growth occurred at the lowest test temperature, 10°C (50°F). Black crappie and BC × WC hybrids also showed the best growth at 18 to 22°C (64 to 72°F), but they grew little or not at all at 10 to 14°C (50-57°F).

In general, crappie have proven to be much less tolerant to handling, much more difficult to train for prepared diet acceptance, and much more susceptible to disease-related mortalities than have all the *Lepomis* taxa evaluated in a similar manner. Generally, black crappie have survived better, been more easily trained to accept prepared feeds, and have shown better growth than the white crappie. The BC × WC hybrid performed intermediately. SIU-C researchers have had difficulty developing triploid induction methods for crappie that provide both high survival and high rates of triploidy, unlike the success which was accomplished with *Lepomis*.

The principal actions taken by University of Nebraska-Lincoln (UNL) participants were to investigate the logistics and feasibility of producing two 10-20 min educational videotapes on selected topics to be covered in the sunfish production manual. The originally proposed plan of action was to do most of the videotape shooting in the first year of the project, and any necessary final shooting and most of the editing and technical production in the second year. Unfortunately, UNL-wide budget cuts and a reduction in production staff plus program priority changes in the electronic media unit responsible for videotape production with the UNL Institute of Agriculture and Natural Resources precluded videotape shooting in the first year of the project. It is expected that UNL participants will now be able to proceed with the proposed production of the two videotapes.

Iowa State University (ISU) and Michigan State University (MSU) personnel have completed drafts of the sunfish culture manual. The individual chapters will be reviewed during spring 1996 and the manual is scheduled for completion by summer 1996.

At SIU-C, juvenile F_1 hybrid sunfish (GS × BG) with a mean weight of 12 g/fish, were stocked (May 23, 1995) at a rate of 5,504 fish/ha (2,228 fish/acre), into 16 ponds averaging 0.037 ha (0.09 acre). Ponds were supplied with one of four practical diet formulations containing crude protein levels of 32, 36, 40, or 44%. Feeding rate was initially 3% of the estimated biomass once a day except on days of sampling. All ponds exhibited nest building activities by June 6 and recruitment of F_2 hybrids in some ponds was apparent by July 18. Feeding rates were reduced to 2% (August 15 through September 26, 1995) when a large amount of feed was noticed left from the previous feedings. This reduction in feeding activity coincided with high temperatures of 30°C (86°F).

MSU researchers have developed semi-purified diets readily accepted by hybrid sunfish (female GS × male BG) and bluegill. The diets which include graded levels of energy, bracket the energy concentrations necessary to determine the optimal protein/energy (P/E) ratio. Appropriate feeding rates for normal growth have been determined for these diets.

Research at Purdue University was initially focused on quantifying key nutritional requirements of hybrid bluegill. Through three separate studies with the hybrid sunfish, growth was relatively low despite offering a broad variety of diets. Prior to conducting the next series of studies on critical nutritional requirements, an evaluation of pure bluegill was conducted. Growth of pure bluegill was double the growth observed with hybrid bluegill. The studies were conducted in the same experimental systems in the same conditions with the same broad variety of feeds. There was also differential use of commercial diets. Results of those studies clearly indicated that diets formulated for trout and salmon were better than diets formulated for catfish. Further, there were clear distinctions within the trout diets. That is, all trout diets are not the same nor is the response in the hybrid comparable to the pure bluegill. Prior to completing the proposed work in the current project, these results will be transferred to the IAC for their consideration.

Researchers at the University of Missouri have been examining the potential to increase growth rates of hybrid sunfish during grow-out, by using feeding schedules that bring out these fishes' compensatory growth response (increased growth following a period of fasting). Hybrid sunfish were held individually in experimental enclosures submerged in larger water-recirculation tanks. Water temperature was maintained at 24°C (75.2°F) as was a 15-h light/9-h dark photoperiod regime. Mealworms (*Tenebrio molitor*) were used as the food in these initial experiments so that daily consumption by individual fish could be accurately determined. Six groups of ten fish were formed. In the group serving as controls, individual fish were fed *ad libitum* every day for 105 d. Fish in the other five treatment groups were fed according to schedules intended to elicit compensatory growth. These schedules involved repeating cycles of no-feeding followed by *ad libitum* refeeding for 115 d. The five treatment groups differed in the number of no-feeding days in the off/on feeding cycles; cycles involving 2, 4, 6, 10, and 14 d of no feeding (hereafter referred to as D2, D4, D6, D10 and D14) were used. After any no-feed period, refeeding continued until the increased appetite associated with the compensatory growth response decayed. In addition to daily consumption, body weights of all fish were determined weekly.

Over the 105 d experiment, mean growth rates of hybrid sunfish in the D2 and D14 groups were 2.1 and 1.5 times faster than the controls that were fed *ad libitum* every day. The growth exhibited by the D2 group was significantly above controls while that of the D14 group was marginally greater. The D4 group showed a mean growth rate that was

1.4 times above controls but not significantly greater.

These results represent the first demonstration that fish can be grown significantly larger than daily-fed controls over identical time periods, by eliciting the compensatory growth response. Growth improvements from compensatory growth appeared to result from increases in both consumption rate and growth efficiency. While best results were observed for the shortest off/on feeding cycle (D2), there was some suggestion from growth responses that longer off/on cycles (>14 d) may be of value.

The primary goal of the University of Wisconsin-Milwaukee (UW-Milwaukee) researchers was to utilize the early life stage feeding technology developed for yellow perch and apply this approach to centrarchids, specifically, black crappie. They selected two early life stages as their starting points for the development of intensive aquaculture strategies. Young-of-the-year (YOY) Wisconsin pond-raised black crappie (*N* = 1,200) were obtained in fall 1994. Under laboratory conditions these fish accepted adult frozen brine shrimp as a transitional food within 3 d and were habituated to commercial starter feed within 14 d. Survival to present is greater than 65%. In addition, UW-Milwaukee researchers obtained several hundred YOY black crappie from a commercial producer in Iowa. Initially these fish were fed "green tank" water organisms, which included copepods, ostracods and smaller cladocerans. These organisms are all much larger than those fed to yellow perch at first feeding. The average length of these fish was 25 mm (1 in); consequently it was necessary to select larger "green tank" water organisms. On day 3 of the experimental feeding they attempted a trial feeding using brine shrimp napulii (BSN). One hour after the introduction of BSN 60-70% of the fish were observed to have BSN in their guts. On day 6 a beef-liver mixture (BLM) was added to the feeding schedule followed by the final phase of habituation to prepared diets. This group of black crappies habituated to formulated starter diet (FSD) within 26 d. This group of fish (*N* = 73) was terminated on September 25, 1995: mean length and weight was 66.8 mm (2.63 in) and 3.92 g, respectively.

One objective of the ISU researchers was to spawn bluegill out-of-season through temperature and photoperiod manipulation under laboratory settings. ISU researchers stocked adult fish at a ratio of two males to four females per 640 L (170 g) tanks in a recirculation system. After an acclimation period, temperature and photoperiod were maintained at 24°C (75.2°F) and 14-h light/10-h dark. They were able to spawn fish during a six month period (December 1994 - May 1995); 40 spawns averaging 20,000 larvae each were obtained from 24 females.

A second objective at ISU was to develop a procedure for tank-rearing larval bluegill. In the first set of experiments, seven commercial diets were initially used for feeding larval bluegill from the onset of exogenous feeding to 28 d posthatch. Although all diets were consumed by the larvae, none were digested and survival was essentially zero for all diets. In the next set of experiments, bluegill larvae were able to digest commercial diets by feeding them BSN (San Francisco strain) for an initial 7 d period and then switching to commercial feed over a 3 d period. Using this protocol, they compared three feeds (Fry Feed Kyowa™ B-250, Hatchery Encapsulon® Grade II and Larval AP-100™) over a 28 d interval. There were no significant ($P \leq 0.05$) differences in growth (length and weight) among the three diets at the end of 28 d, but survival was significantly higher in fish fed Fry Feed Kyowa™ B-250. In a final experiment, larval bluegill were fed Fry Feed Kyowa™ B-250 after feeding them brine shrimp for 3, 7, or 14 d with an additional 3 d weaning period with mixed feeding. At the end of the study, larvae fed brine shrimp for 14 d had significantly higher growth and survival than did larvae in the 3 d and 7 d treatment groups. Larvae fed brine shrimp for 7 d had significantly longer length and higher survival than did larvae fed brine shrimp for only 3 d. The protocol for tank-rearing larval bluegill should include using brine shrimp prior to using a commercial diet.

WORK PLANNED

Data related to crappie culture will be completed and analyzed in 1995. This information will then be reported in next year's termination report.

Because of the inability of the UNL participants in Objective 2 to obtain videotape footage in the first year of the project, a major effort will be mounted in the second year to complete all the necessary videotape shooting and editing. If necessary, the shooting will be done by employing freelance videographers and/or editors, or (paid) videography assistance from ISU or MSU - when appropriate and feasible. Most of the videotape shooting will be done at aquaculture facilities or project sites of the latter two institutions. Over the winter, plans will be made for in-depth videotape shooting over the spring and summer of 1996 with ISU and MSU researchers. Present plans are to complete all necessary editing and technical production before September 1, 1996.

MSU researchers have initiated a study to determine performance parameters of the experimental diets relative to a commercial control diet. It is expected this study will establish an optimum energy concentration for sunfish performance and the basal metabolic energy requirements for the experimental conditions employed. Next year, optimum protein/energy (P/E) requirements will be completed.

UW-Milwaukee researches will attempt the laboratory spawning of their captive brood fish by manipulating temperature and photoperiod, if necessary they will use spawning induction substances. In addition, they will organize and conduct field collections of adults in spawning condition in 1996. An attempt will be made to intensively rear black crappie using "green tank" water from the onset of first-feeding.

Using the feeding and spawning protocols developed for larval bluegills, ISU researchers will spawn hybrid bluegills (GS × BG) out-of-season during fall 1995 and complete their assigned tasks under this proposal.

IMPACTS

- Coupled with the NCRAC sponsored development of improved intensive larval sunfish culture techniques at Iowa State University under the direction of Joe Morris (Bryan et al., 1994), commercial fish farmers have the tools to establish stocks of polyploid sunfishes.
- NCRAC funding permitted SIU-C to leverage funding from the American Fishing Tackle Manufacturing Association to evaluate benefits of triploid sunfish in recreational fishing ponds. The supply of triploids to recreational fisheries could provide a new

market for regional producers.

- Developing diets specifically for targeted species results in maximum performance at the lowest possible cost. Purdue University research directed at minimizing costs of feeds will help to maximize profit to the producer.
- It now appears that the intensive culture technology developed for yellow perch can be applied to black crappie. Also, YOY (30-60 d old) pond-produced black crappie can habituate to prepared diets within 26 d; YOY (100 d old) pond-produced black crappie can habituate to prepared diets within 14 d . The potential for the intensive culture of black crappie looks very promising.
- It is now possible to induce bluegill to spawn in the laboratory out-of-season by manipulation of temperature and photoperiod without the use of hormones. This protocol allows for the production of bluegill larvae, regardless of season, for both laboratory studies and aquaculture stocking.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED

See Appendix.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1990-92	$130,758	$96,710				$96,710	$227,468
1992-94	$149,867	$313,330	$3,700[a]	$10,000[b]	$34,030[c]	$361,060	$510,927
1994-96	$174,999	$177,300	$12,012[d]			$189,312	$364,311
TOTAL	$455,624	$587,340	$15,712	$10,000	$34,030	$647,082	$1,102,706

[a]American Fishing Tackle Manufacturing Association ($3,200) and KOCH Industries-Foch Flexirings ($500)
[b]National Science Foundation-STARS Research
[c]Illinois Natural History Survey ($29,830); Kansas Department of Wildlife and Parks ($3,000); and City of Pittsburg, Kansas ($1,200)
[d]Farmland Industries, Inc.

SALMONIDS

Progress Report for the Period
September 1, 1994 to August 31, 1995

NCRAC FUNDING LEVEL: $200,000 (September 1, 1994 to August 31, 1996)

PARTICIPANTS:

Terence B. Barry	University of Wisconsin-Madison	Wisconsin
Paul B. Brown	Purdue University	Indiana
Konrad Dabrowski	Ohio State University	Ohio
Donald L. Garling	Michigan State University	Michigan
Terrence B. Kayes	University of Nebraska-Lincoln	Nebraska
Jeffrey A. Malison	University of Wisconsin-Madison	Wisconsin
Ronald R. Rosati	Illinois State University	Illinois
Extension Liaison:		
Ronald E. Kinnunen	Michigan State University	Michigan
Non-funded Collaborators:		
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Nebraska Game & Parks Commission	Calamus State Fish Hatchery, Burwell	Nebraska
Forrest Sawlaw	Archer Daniels Midland, Peoria	Illinois
Wisconsin Department of Natural Resources	Lake Mills State Fish Hatchery	Wisconsin
Y. Victor Wu	National Center for Agricultural Utilization, ARS,USDA, Peoria	Illinois
Michael Wyatt	Sandhills Aquafarm, Keystone	Nebraska

PROJECT OBJECTIVES

(1) Develop practical rainbow trout diets using regionally available feed ingredients, including fish meal analogs.

(a) Evaluate the effects of feed binders in diets formulated from locally available plant ingredients on trout performance and on the stability of trout feces to enhance the removal of solids from hatchery effluents.

(b) Evaluate the effectiveness of phytase treatment of plant feed ingredients on phosphorus and protein availability to trout.

(c) Develop and evaluate fish meal-free diets using regionally available feed ingredients.

(2) Use stress response as a selection tool for developing strains of trout having improved performance under conditions found in the North Central Region (NCR).

(3) Use stress and performance responses in trout to evaluate culture system design and operation under practical conditions.

ANTICIPATED BENEFITS

The research proposed to develop less-polluting lower-cost diets from regionally available ingredients, including fish meal analogs, will benefit existing aquaculturists facing stricter regulatory pressures to reduce waste nutrients in effluents, as well as new aquaculturists facing increasingly complex permitting processes. Using regionally available plant protein and animal by-product protein sources as substitutes for fish meal in trout diets should reduce the cost of feed manufacture and help produce diets that are less polluting. The research proposed to evaluate and develop improved trout strains will delineate practical methods for producing improved regional strains with enhanced growth rates, feed conversion, and disease resistance that will improve overall production efficiency and help decrease effluent wastes.

Evaluation of the best available "less-polluting" diets made from regionally available ingredients and of trout strains presently available to regional fish farmers will be initiated as part of the research proposed to evaluate culture system design and operation under practical conditions. Using a holistic approach and appropriate field testing, both diet and genetic strain will be treated as an integral part of system design and operation, and the performance of the different diets and different strains will be compared in cylindrical tank versus raceway production systems, using pure oxygen supplementation.

This overall approach will provide a strong element of integration among the proposed project's three objectives and should help facilitate the transfer of the new products and technologies developed to practicing fish farmers, potential fish farmers, feed manufacturers, aquaculture facility designers, and other user groups. This will be done through research publications, extension fact sheets and bulletins, and other appropriate outreach mechanisms.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1

Investigators at Michigan State University (MSU) have completed all laboratory work which includes phosphorus content of feeds, different life stages of coho and chinook salmon, and solid wastes on a monthly basis throughout the production cycle. Records have been collected from Michigan Department of Natural Resources Platte River Fish Hatchery personnel on feeding rates, growth rates, survival, and waste retrieval for coho and chinook salmon. In general, incomplete hatchery records and missing data has indicated the need for better monitoring and record keeping if the mass balance approach is to give better estimates of phosphorus concentrations than chemical estimates of phosphorus concentrations in their effluent.

Studies by Ohio State University (OSU) investigators on five experimental diets fed to triplicate groups of rainbow trout (initial weight 205 ± 13.5 g; 7.23 ± 0.48 oz) are being conducted using circular tanks at the Piketon Research and Extension Center. These studies are evaluating the use of fish-meal analog (mixture of four animal by-products) as the replacement of 25, 50, 75 and 100% of menhaden fish meal protein. To date, fish growth did not differ significantly among treatments. Fillets were obtained from these fish and the chemical composition differed significantly among treatments. Fecal samples were collected in 1995 and are currently being analyzed to determine the apparent digestibility of nutrients.

Research at Purdue University was initially focused on quantifying nutritional availability of critical nutrients known to pollute receiving bodies of water: nitrogen and phosphorus. Through the initial project, phosphorus availability from common feed ingredients was measured as well as nutrient interactions that would be useful in dietary formulation. The initial studies are complete and several manuscripts have been submitted for publication. It seems clear from the results that availability of phosphorus from feedstuffs fed to rainbow trout is different from existing values for other species and that the values are not additive. That is, we cannot simply add the availability of phosphorus from soybean meal and fish meal and arrive at a precise availability of phosphorus from diets containing both ingredients. In the second series of studies, availability of phosphorus was measured in Atlantic salmon, and it is clear from those studies that phosphorus availability is distinctly different from the availability of phosphorus in rainbow trout. An additional study was conducted in which the availability of crude protein was measured and found to vary with level of substitution in the diet. These data will dramatically change the general approaches to formulating salmonid diets in the future.

In the most recent project, a dietary formulation was identified that, when fed to fish of an initial weight of 60 g (2.12 oz), weight gain and other response variables were within 90% of fish fed a positive control diet. That formulation contained 40% soybean meal and corn co-products as the primary ingredients, and no fish meal. Another diet containing no fish meal was identified that was almost as good as the high soybean diet, but the primary protein source was one of the newer soy protein concentrates. No adverse responses were identified in fish fed the soybean diet, but flavor was significantly changed.

OBJECTIVE 2

In October 1993, approximately 400 1-year-old rainbow trout were obtained from the Seven Pines Hatchery, Lewis, Wisconsin, and subsequently reared in replicate flow-through tanks at ambient water temperatures by University of Wisconsin-Madison (UW-Madison) investigators. In February, May, and August 1994, each fish was weighed, measured, subjected to a one-minute acute handling stressor, and sampled for blood either 1, 3, or 6 h following the stressor. The serum was subsequently analyzed for cortisol, glucose, and chloride concentrations. The UW-Madison investigators found that serum cortisol levels at 3-h post-stress was the physiological measure that was most strongly correlated (in an inverse manner) with superior performance. For example, fish having low 3-h post-stress cortisol levels had an average specific growth rate (SGR) of 0.54, as compared to an average SGR of 0.41 in unselected fish. This suggests that the rate at which cortisol levels return to baseline *afte*r a stressor is an excellent predictor of performance. A group of fish having this type of response is currently being held and will be bred later in the year.

OBJECTIVE 3

In the autumn of 1994, University of Nebraska-Lincoln (UNL) investigators with the help of personnel of the Nebraska Game and Parks Commission at the Calamus State Fish Hatchery conducted an 8-week study comparing the effects of culturing rainbow trout in cylindrical tanks at "Piper rearing densities" of 0.45, 0.9, and 1.35 [(weight of fish in pounds/cubic feet of water)/length of fish in inches)]. The growth and mortality rates and "Goede health index" of young trout reared at these densities were compared using experimental procedures described in the original proposal that assured similar water quality and turnover rates and similar loading rates (pound of fish/gallon per min of water flow) across all three densities. (The traditional maximum recommended Piper rearing density for rainbow trout is 0.5). In this study, no significant differences in the parameters measured were found between rearing densities. A stress challenge test on fish from all three rearing densities was performed at the end of the study, and blood samples were collected and prepared for analyses of serum cortisol, glucose and chloride levels by UW-Madison investigators.

In the spring of 1995, an 8-week study was done at the Calamus hatchery comparing the growth and mortality rates and Goede health index of young rainbow trout cultured in (plug-flow) raceways at Piper rearing densities of 0.45 and 0.9. To account for changes in water chemistry down the lengths of the raceways, replicate treatment groups of fish at each density were assigned to two similarly sized sections (separated by baffles with slotted bottom screens) in similar positions along the lengths of each of five raceways. As in the study with cylindrical tanks, no significant differences in the parameters measured were found between rearing densities in raceways - accounting for differences in water chemistry. Again, at the end of the raceway study, stress challenge tests on trout reared at the two rearing densities were performed, and blood samples were collected and prepared for analysis of serum cortisol, glucose and chloride levels by UW-Madison investigators.

In the summer of 1995, an 8-day pilot study was done using cylindrical tanks equipped with sealed packed columns to provide supplemental oxygen to examine the effects on critical water chemistry parameters of culturing young trout at Piper rearing densities of 0.45 and 0.9 in this type of intensive production system. The water chemistry parameters monitored during the course of the pilot study were: dissolved oxygen and carbon dioxide, temperature, pH, total dissolved gas pressure, and ΔP (the difference between measured and saturated total dissolved gas pressure, as calculated for a given set of conditions). This pilot study was done in advance of a production-scale field trial to compare the growth, performance, health and stress responses of young trout reared in raceways versus cylindrical tanks equipped for oxygen supplementation. The results of the pilot study indicated that it should be feasible to produce rainbow trout in oxygen-supplemented cylindrical tanks at Piper rearing densities as high as 0.9 without adverse effects.

WORK PLANNED

OBJECTIVE 1

MSU investigators will complete the mass balance model during the second year of study. They have also started a 6-month feeding experiment with rainbow trout to determine zinc-phytin interactions in soybean meal based diets. Their hypothesis is that phytic acid may bind zinc, thereby impairing production or activity of zinc-dependent digestive enzymes (carboxypeptidase, alkaline phosphatase) and insulin production/storage. Results expected are reduced protein and/or phosphorus utilization in feeds that are not treated with phytase or supplemented with zinc and phosphorus.

Proposed binder work on impact on feces stability has been completed by Dr. George Ketola at the Tunison Fish Nutrition Laboratory in Cortland, New York. MSU investigators will plan additional studies in consultation with Dr. Ketola to determine the impact of binders on mineral availability in plant protein based diets.

Research at Purdue University will continue refinement of the all plant diets. Specifically, the high soybean diet will be supplemented with several dietary additives that are legal in the United States. That study will focus on pigmentation of trout fed an all-plant diet, flavor additives, plant lipid sources and essential amino acid supplementation. Results from this second study will be beneficial in development of a regionally available diet for trout.

The proposed field testing of the two best experimental trout diets developed by the project in Year 1 from regionally available feed ingredients will be done by UNL investigators and their cooperators, as outlined in the original proposal and in consultation with the MSU, Purdue and Illinois State University researchers who developed the diets. The conduct, size, and exact design of the field trial to test these diets will depend on the provision of good quality milled feeds and the availability of fish and production facilities. Present plans are to conduct the feeding trial at the Calamus State Fish Hatchery and to compare the effects of the experimental diets to the normal production feed in relation to fish growth and performance, as well as effluent water quality.

OBJECTIVE 2

The comparison, by UNL investigators and a Nebraska private producer, of growth, performance and stress responses of Donaldson versus Kamloop strains of rainbow trout under production conditions will be done in line with procedures described in the original proposal. One possible variation from this is that the comparison may be done in net-pens rather than raceways, to better meet the intent of the project and depending on available facilities. Regardless, appropriate experimental procedures will be employed.

The fish at UW-Madison facilities are currently (fall 1995) 3 years old and sexually mature. The selected brood fish will be allowed to ovulate naturally and the eggs from individual females will be fertilized with the pooled milt from selected males. Eggs and milt from brood stock chosen randomly from the original Seven Pines population will be fertilized in an identical manner, and these will serve as the non-selected controls. The offspring from both the selected and control fish will be reared using standard procedures and identical environmental conditions. The rearing environment will be kept suboptimal (i.e., high rearing densities, suboptimal water temperatures) in order to evaluate the growth and performance of the fish subjected to the types of chronic stressors commonly associated with intensive fish farming in the NCR. Throughout the grow-out period, performance parameters including growth, feed conversion and incidence of disease and mortalities will be monitored. The physiological stress responses of the offspring will be characterized at the termination of the experiment, and perhaps at other times, by applying acute stress challenge tests as described above.

IMPACTS

- The work by investigators at OSU provide strong evidence that fish meal free diets based on protein from animal by-products can be used in rainbow trout culture.

- The field trials conducted by UNL investigators and their Nebraska cooperators, both in the present and past salmonid projects, have verified the laboratory findings of UW-Madison researchers that rainbow trout can be readily produced at much higher rearing densities than traditionally recommended. The Nebraska studies have verified these laboratory findings under practical rearing conditions, and have also demonstrated that trout can be produced in cylindrical tanks at as high a rearing density as in raceways.
- The availability of rainbow trout strains with improved growth rate, feed conversion and disease resistance will greatly improve the production efficiency of private and public fish hatcheries throughout the NCR. Additionally, the availability of quality trout eggs from within the region will help reduce the need that regional trout farmers currently have for importing eggs from the west coast.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED

See Appendix.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1994-95	$102,042	$103,987		$8723[a]	$15,000[b]	$127,710	$229,752
1995-96	$97,958	$104,096		$9,867[a]		$113,963	$211,921
TOTAL	$200,000	$208,083		$18,590	$15,000	$241,673	$441,673

[a]University of Wisconsin Sea Grant Program

[b]International Collaborative Program for OSU to work jointly with the National Fisheries University of Pusan, Korea

CRAYFISH

Project Termination Report for the Period
September 1, 1992 to August 31, 1995

NCRAC FUNDING LEVEL: $50,000 (September 1, 1992 to August 31, 1994)

PARTICIPANTS:

Paul B. Brown	Purdue University	Indiana
Harold E. Klaassen	Kansas State University	Kansas
Robert J. Sheehan	Southern Illinois University-Carbondale	Illinois
Extension Liaison:		
Jeffrey L. Gunderson	University of Minnesota-Duluth	Minnesota
Non-Funded Collaborators:		
Carl Richards	University of Minnesota-Duluth	Minnesota
Robert Wilkinson	Southwest Missouri State University	Missouri

REASONS FOR TERMINATION

The objectives of this project were completed and the NCRAC Industry Advisory Council did not ask for a second project.

PROJECT OBJECTIVES

(1) Complete a study of the status of the crayfish industry in the north central states, relative to its extent, culture operations in use, market characteristics, and problems which need to be addressed by research.

(2) Complete a report on indigenous crayfish species appropriate for culture in the North Central Region (NCR), to include species life histories, ranges of distribution, economic assessment of appropriate culture production systems, a bibliography of pertinent literature, and a summary of critical information gaps.

(3) Conduct preliminary trials evaluating the performance of several promising indigenous species in pond culture.

PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1

Within the NCR, 73 crayfish aquaculturists were identified by state extension contacts. Those individuals were sent a survey form and asked to respond to a series of questions. Based on the responses, crayfish production in the region appears to be under 10,000 kg (22,046 lb) per year. It is felt that this may be an underestimate of total production as several of the larger producers did not respond despite numerous mailings of the survey. The majority of those who responded (71%) indicated they grew crayfish in polyculture with other fin fish. The primary market for crayfish was bait, as a hard-shell product (78% of respondents). Respondents felt there was opportunity for expansion in both the bait (hard- and soft-shell) and human food market. They also indicated that the best return on investment was as tail meat or as a hard-shell bait product. The principal problem areas identified were markets for their products and growth rates of the various species native to the region.

OBJECTIVE 2
A report on the life history and culture potential of four indigenous crayfish species (*Orconectes immunis, O. virilis, O. nais,* and *Procambarus acutus*) is nearing completion and will serve as an important source of information for new culturists interested in crayfish aquaculture in the NCR. Information is presented on the life history, biology, distribution, and an assessment of appropriate culture systems. A bibliography and summary of critical information gaps for each of the four species is also included.

OBJECTIVE 3
Research was conducted at Purdue University, Southern Illinois University-Carbondale (SIU-C) and Kansas State University (KSU) to evaluate the growth, production and survival of several indigenous crayfish species in various pond culture systems.

Research at Purdue University was designed to compare growth of several of the region's native species of crayfish in side-by-side comparisons. In the first year of the study, *O. virilis*, *O. immunis*, *O. rusticus* and *P. acutus* were evaluated. In the second year of the project, *O. virilis*, *O. propinquus*, and *O. longidigitus* were compared. *O. virilis* grew better than the other crayfish in both years and their yield was higher than the other crayfish in the first year. However, yield was similar in the second year among all crayfish species evaluated.

Research at SIU-C was conducted to compare the growth and production of three species of crayfish (*P. acutus, O. virilis,* and *O. immunis*) under polyculture conditions, and compare growth and production of crayfish under two production strategies: (1) artificial destratification/aeration, use of prepared feeds, perpetually filled ponds, and seining (first year); and (2) winter cover-crop production, fall-winter draw down, and harvest via baited traps (second year).

Four ponds (0.06 ha; 0.15 acre) were aerated and four were not in Year 1. Each pond was stocked with about 8,340 young-of-the-year (YOY) crayfish. Only *O. immunis* and *O. virilis* were stocked in the first study year. All three species were examined in the second year. Heavy rains in November precluded planting in the fall prior to Year 2, so cover-crop ponds were planted with Clark Wheat at a rate of 120 kg seed/ha (107 lb/acre) in April of Year 2. The wheat reached a height of 20 cm (7.9 in) prior to flooding.

The specific findings over the two years of study by SIU-C were as follows.

- Bottom mean dissolved oxygen (DO) concentrations were significantly lower in non-aerated ponds and in cover-crop ponds than in aerated ponds.
- Bottom temperatures were about 1°C higher on average in aerated versus non-aerated ponds, and the difference was significant.
- Average daily weight gain was significantly higher in aerated versus non-aerated ponds and cover-crop ponds.
- *P. acutus* grew faster than the other two species and *O. virilis* grew significantly faster than *O. immunis*. YOY crayfish began reaching harvestable size (70 mm total length [TL]; 2.76 in) in appreciable numbers by July.
- Mean weights were significantly greater in aerated (15.9 g; 0.56 oz) versus non-aerated ponds (11.8 g; 0.42 oz).
- Harvest from the cover-crop ponds was extremely low (8 kg/ha on average; 7.1 lb/acre) versus the aerated ponds (221 kg/ha on average; 197.2 lb/acre).

- *O. nais* appears to be a subpopulation of *O. virilis*, rather than a true species, based on starch-gel electrophoresis.
- The percent edible tail meat was higher for *O. immunis* (21.9%) than for *P. acutus* (19.3%), *O. virilis* (19.6%) and a sample of *P. clarkii* (16.1%) that had been obtained.

At KSU growth, survival, and harvest of the crayfish *O. nais* were evaluated in three 0.20 ha (0.5 acre) farm ponds. The water quality of these ponds varied considerably but was typical of many Kansas farm ponds.

Each pond was to be stocked in mid-summer with a low density (3/m^2; 0.3/ft^2) of YOY crayfish to allow for maximum growth rate. Ponds were not fed or aerated. Growth, survival (both summer and winter), and harvest were evaluated through two growing cycles, 1993-94 and 1994-95. Prior to stocking, the ponds were to be poisoned to remove existing crayfish. Due to unusually wet weather during 1993, only one pond was poisoned and stocked at the low density. The other two ponds were intensively seined and trapped; crayfish that remained in the pond were used for the study. During 1994-95 all three ponds were poisoned and stocked as proposed.

Edible Size Crayfish
The size of crayfish considered edible or the minimum marketable size varied somewhat among the three research groups. Crayfish were judged to be edible size in the KSU study if they were larger than 38 mm (1.5 in) carapace length (approximately 76 mm TL; 3.0 in). This is somewhat larger than the 70 mm (2.8 in) TL (approximately 11-12 g or 38-41 crayfish/lb) judged as edible size in the SIU-C research. Crayfish exceeding 47 mm (1.9 in) carapace length (approximately 94 mm TL; 3.7 in) were designated jumbo size in the Kansas State study. Crayfish weighing 15-18 g (approximately 25 to 30 crayfish/lb) were considered minimum marketable size in the Purdue study.

Crayfish did not generally reach edible size during their first growing season but attained edible and jumbo size by the following June. At the end of the growing season (both years), average carapace lengths (CL) of YOY crayfish varied significantly among ponds and ranged from 23 to 41 mm (0.9 to 1.6 in).

During June of 1994 and 1995 all three ponds were intensively trapped with minnow traps over a two week period. The catch was high at first, but fell off rapidly. Generally, after ten trap nights at least 90% of the harvested crayfish had already been captured. Ponds with larger crayfish trapped out more quickly. The weather was cool during the beginning of June 1995 and trapping success was low, but success increased rapidly as water temperatures warmed. Size of yearling crayfish harvested in June varied from pond to pond and year to year and ranged from 8% edible size (no jumbo) to 100% edible size (87% jumbo).

Crayfish survival was variable. Summer survival (stocking time to fall) ranged from 12% to 78%. Winter survival (fall to spring harvest) ranged from 3% to 55%. Winter survival was consistently lower than summer survival.

IMPACTS

- The crayfish producer survey was the first attempt at defining the status of crayfish aquaculture in the NCR, the potential for expansion, and the current crayfish culture problems/impediments.
- A manuscript is being written that succinctly summarizes the biological

characteristics and examines the aquaculture potential of four native crayfish species. The document will be a valuable tool for aquaculturists and extension personnel in the region.

- Growth of several species was compared and *O. virilis* appears to be the best of those studied when reared in pond monoculture.
- Several species grew to minimum marketable size for human consumption in one growing season and many attained jumbo size by the following June.
- Aeration improves growth and production in crayfish ponds, but providing a cover crop did not.
- All three species evaluated at SIU-C have their advantages: *P. acutus* reaches harvestable size early in the production season, *O. virilis* exhibited good growth and survival, and *O. immunis* had the highest percentage of edible tail meat.
- YOY crayfish can be successfully stocked.
- Most of the marketable-size crayfish can be harvested from small ponds within two weeks.
- Survival is quite variable and dependent on weather and pond conditions. Winter is a critical period. Aeration would improve survival.

RECOMMENDED FOLLOW-UP ACTIVITIES

The two primary problems identified by current aquaculturists raising crayfish in the region were market assessment and development and crayfish growth rates. Marketing studies for freshwater crustaceans are lacking and are needed for developing business plans. Numerous factors can effect growth and virtually all need to be explored with crayfish. Crayfish exhibit density-dependent growth and survival, that is, as density increases, growth and survival decrease. This happens with various species of fish as well, but is usually solved by in-depth studies. There is also a need for a biocide registered for use on crayfish which would allow for more active management of production ponds.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1990-95					$61,960[a]	$61,960	$61,960
1992-93	$25,000	$29,439				$29,439	$54,439
1993-94	$25,000	$28,610				$28,610	$53,610
TOTAL	$50,000	$58,049			$61,960	$120,009	$170,009

[a]State of Indiana, Business Modernization and Technology Center, through the Purdue University New Crops Center

EFFLUENTS

Project Termination Report for the Period
September 1, 1992 to August 31, 1994

NCRAC FUNDING LEVEL: $153,300 (September 1, 1992 to August 31, 1994)

PARTICIPANTS:

Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin
James M. Ebeling	Ohio State University	Ohio
Konrad Dabrowski	Ohio State University	Ohio
Reginald D. Henry	Illinois State University	Illinois
Kyle D. Hoagland	University of Nebraska-Lincoln	Nebraska
Terrence B. Kayes	University of Nebraska-Lincoln	Nebraska
Joseph E. Morris	Iowa State University	Nebraska
Ronald R. Rosati	Illinois State University	Iowa
Extension Liaison:		
LaDon Swann	Purdue University	Illinois/Indiana
Non-Funded Collaborators:		
John Hyink	Glacier Springs Trout Hatchery/Alpine	Wisconsin
Iowa Department of Natural Resources (DNR)	Fairport State Fish Hatchery	Iowa
Iowa DNR	Rathbun State Fish Hatchery	Iowa
Myron Kloubec	Kloubec's Fish Farm	Iowa
Bill Johnson	Rushing Waters Fisheries	Wisconsin
Dave Smith	Freshwater Farms of Ohio, Inc.	Ohio
John Wolf	Glacier Springs Trout Hatchery/Alpine	Wisconsin
Michael Wyatt	Sandhills Aquafarms	Nebraska

REASON FOR TERMINATION

Completion of project timetable.

PROJECT OBJECTIVES

(1) Characterize aquaculture effluents from four types of aquaculture production systems: pond culture, flow through culture (raceway), cage culture, and recirculating systems.

(2) Generate a data base from these four types of production systems to help promote a reasonable choice of effluent discharge regulations by government agencies.

PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1

POND PRODUCTION SYSTEMS

Fairport State Fish Hatchery, Iowa

Water quality was monitored in four culture ponds stocked with channel catfish, *Ictalurus punctatus*, fingerlings at Fairport State Fish Hatchery near Muscatine, Iowa during 1993. Data were collected during the culture season and at harvest to analyze pond and effluent water quality. During the course of the growing season, water temperature, nitrates, and total suspended solids levels decreased while dissolved oxygen (DO), ammonia, un-ionized ammonia and 5-day carbonaceous (organic) biological oxygen demand ($CBOD_5$) increased.

Analysis of data collected at harvest revealed that total phosphorus and total solid levels increased substantially in the pond effluents compared to those within the ponds. Towards the latter stages of fish harvest, $CBOD_5$ levels significantly increased within the ponds; effluent quality significantly deteriorated, having increased levels of total phosphorus, total nitrogen, $CBOD_5$, total solids, and total suspended solids. Fish biomass was a positive influence on $CBOD_5$.

<u>Kloubec Fish Farm, Iowa</u>
Samples were obtained from Kloubec's channel catfish and hybrid sunfish ponds in early and late October 1993. During the sampling period, two ponds had elevated levels of nitrites and three ponds had elevated levels of nitrates compared to earlier sampling periods. However, $CBOD_5$ levels decreased in all ponds during this sampling period. The two ponds with the highest levels of $CBOD_5$ at this time had been harvested the previous month. The act of seining probably resulted in direct increase in $CBOD_5$ levels compared to those ponds that had not been harvested.

Ponds at Kloubec's Fish Farm had higher $CBOD_5$ levels than did the flow-through situation at the Rathbun State Fish Hatchery, but were similar to pond levels at the Fairport State Fish Hatchery. However, the nitrogenous compounds levels were low. The two ponds with the highest feed levels had the highest $CBOD_5$ levels.

RACEWAY (FLOW THROUGH) PRODUCTION SYSTEMS
<u>Rathbun State Fish Hatchery, Iowa</u>
The effects of a flow-through aquaculture facility, Rathbun Fish Hatchery, Iowa, were assessed in 1993. Significant differences ($P = 0.10$) were determined in both water quality and invertebrate parameters at six sample sites. Sites closest to the culture facility had elevated levels of several nitrogenous and phosphorus compounds compared to sites at the water intake and Chariton River. Main production factors influencing water quality parameters at sites were those taking place within the main hatchery building (flow, fish biomass, feed quantity and quality). Invertebrate groups, both zooplankton and other macroinvertebrates, did not differ between the upstream and down-river stations.

The overall conclusion concerning this data set is that the effects of aquaculture effluents from this hatchery are minimal at best on both chemical and biological factors. High flows resulting from flood conditions caused increased dilution of aquacultural effluents. The 1993 field season had the worst flooding in the state's history. Thus, data collected during this period may not be representative of a typical year where some hatchery effects may have been seen under more normal conditions.

<u>Sandhills Aquafarms, Nebraska</u>
The goal of the University of Nebraska-Lincoln (UNL) research was to monitor key water quality parameters above and below Sandhills Aquafarms, a modern trout production facility on Whitetail Creek in western Nebraska. Whitetail Creek is a spring-fed, first order stream with relatively constant flow and good water quality. Sandhills Aquafarms consists of twelve 2.4×33.5 m (8 ft $\times$ 100 ft) raceways with total flows of 23.5 m^3/min (6,200 gpm) and annual production rates of rainbow trout of 77,100 kg/year (170,000 lb/year). Four sites

were established above the facility and four below to obtain reliable, representative physicochemical measurements and water samples for laboratory analyses.

It was clear that several water quality parameters continued to differ consistently above versus below the aquaculture facility, particularly DO, pH, ammonium-nitrogen, total nitrogen, orthophosphate, and phosphorus. Total suspended solids and turbidity showed no consistent trends. While temperature and biochemical oxygen demand (BOD) appeared to exhibit relatively little difference above and below the facility (although even these differences were consistent), downstream decreases in DO and pH, and increases in ammonium-nitrogen, total nitrogen, total phosphorus, and orthophosphate were evident. These data clearly indicate that water quality was altered downstream from the facility in both 1993 and 1994.

Rushing Waters Fisheries, Wisconsin

Rushing Waters Fisheries is one of the most productive commercial rainbow trout hatcheries in Wisconsin. It has earthen raceways and ponds with a total flow approximately half that of the Nebraska Sandhills operation. As such, it is representative of the more typically sized private trout production facilities in the North Central Region (NCR). This facility is supplied by groundwater wells and springs of moderate conductivity (between 400-600 µS) and is located at the head of a small creek that is a tributary to Blue Springs Creek in Jefferson County, Wisconsin.

Alterations in water quality occurred in the effluents of the three chains of raceways as compared to the source waters entered at the head of each raceway chain, and the water quality of the combined effluent in the creek leaving the property. Increases in BOD, total suspended solids, total ammonia nitrogen, nitrite-nitrogen, soluble reactive phosphorus, and total phosphorus were evident. Under typical production conditions these changes were slight, but on at least one occasion raceway cleaning activities created more elevated conditions of total suspended solids and total phosphorus in the creek leaving the property.

The effluents from the earthen production raceways had slightly lowered levels of nitrate-nitrogen compared to the source water. It seems reasonable that the natural primary and secondary productivity in the earthen bottomed rearing units would utilize nitrate. Dissolved oxygen levels in the groundwater well sources tended to be slightly lower than in the effluents from the raceways. Use of aerating devices in the rearing units kept DO levels high, and the level in the newly pumped well water probably had not yet had enough contact with the atmosphere to reach full saturation before sampling. Source water samples were taken from an open reservoir rather than from groundwater wells, and water from this reservoir had slightly higher levels of solids, ammonia, and phosphorus than the well water sources. This difference was slight, however, in comparison to the general differences between the source waters and the effluents.

Alpine Farms, Wisconsin

Tank rearing of yellow perch and whitefish at Alpine Farms, Sheboygan Falls, Wisconsin was investigated to characterize the effluents produced by alternative regional aquaculture species. Yellow perch and whitefish tank effluents produced changes in water quality parameters similar in direction and magnitude to those of the other flow through rearing situations. Differences appeared to be controlled by production conditions (water exchange, loading, and ration level) rather than by the species reared.

Glacier Springs Hatchery, Wisconsin
The intended opportunity to examine the changes in effluent water quality during the renovation of a former hatchery that had been inactive for over a decade didn't materialize during the project period, due to changes in the owner's plans. A representative set of before renovation water quality data was gathered, which would be suitable for comparison if future renovation occurs. Emphasis was shifted to the Rushing Waters Hatchery study when plans for renovation were delayed.

CAGE CULTURE PRODUCTION SYSTEMS

Trout Culture
Freshwater Farms of Ohio's trout cage culture facility is located near Urbana, Ohio in an abandoned quarry. The site consists of four separate quarry lakes, two of which discharge into a third, which together with the fourth, discharge into the Mad River. A total of ten sampling sites were monitored, including spring inflow into two lakes, the cage culture site at two depths, the discharge from the production lake into a settling lake, the discharge into the Mad River from the settling pond, discharge from an unused lake into the Mad River, and the Mad River upstream and downstream from the discharges.

For all measured parameters, there were no significant differences. There was no negative impact of Freshwater Farms of Ohio's trout cage culture operation on the water quality of the quarry lakes or the receiving water of the discharge. In fact, in most cases significant improvement occurred due to the diluting effect of the quarry discharges.

Channel Catfish Culture
The Piketon Research and Extension Center (PREC-OSU) has a small demonstration cage culture operation in a 1.8 ha (4.4 acre) reservoir located at the facility. The cage culture operation reflects what a small farmer could easily build in a farm pond for the production of channel catfish and for trout grow out in the winter months. The system was lightly stocked over the spring months with trout and yellow perch fingerlings and then heavily stocked with channel catfish (850 kg; 1,874 lb) in mid-summer.

The impact of the small scale cage catfish cage culture operation at PREC-OSU is not easily characterized due to the input from the Center's wastewater treatment plant. Still most water quality parameters were typical of catfish production ponds.

RECIRCULATING SYSTEMS

The facilities studied at Illinois State University (ILSU) included two recirculating aquaculture systems (RAS) stocked with Nile tilapia (*Oreochromis niloticus*). The first system consisted of a 18,927-L (5,000-gal) culture tank, a settling tank particle filter, a vertical screen submerged media biofilter and an oxygen column. The second system consisted of a 170,343-L (45,000-gal) culture system, a drum microscreen particle filter, a submerged media biofilter and oxygen columns. The second system is similar in design, although smaller in scale, when compared to operating commercial systems found in the private sector. The second system was producing 226.8-453.6 kg (500-1,000 lb) of live tilapia each week during the time of these trials.

Data collected on two different RASs demonstrate that RAS effluents contain elevated levels of total solids, settleable matter, BOD, forms of nitrogen (excluding non-ionized ammonia), phosphorus, and reduced concentrations of DO, which agree with previous RAS studies.

OBJECTIVE 2
The combined data sets from these investigations have been tabulated and attached, along with an extensive bibliography concerning aquaculture effluents, as appendices to the Project Termination Report Part II. This data set and references provide a single source overview of effluent water quality from representative regional aquaculture production facilities.

IMPACTS
Data from the recirculating system study has already been used by a private sector aquaculturist in developing a new large recirculating system that meets USEPA compliance. It is anticipated that as this data base is made available to the industry, many more actual applications will occur. Aquaculturists can use this data to take a proactive stance in helping environmental regulatory agencies compose practical aquaculture discharge regulations. Aquaculturists may also use the data collected as baseline values in research to determine the efficiency of newer effluent treatments and best management practices (BMPs) designed to reduce the impact of effluent discharges. Practices that alleviate effluent problems may result in more efficient operation of the hatchery facility and economic savings, and also decrease environmental impacts. This information will help protect the quality of water resources and may alleviate the fears of the general public as to the perceived polluting aspects of aquaculture systems.

RECOMMENDED FOLLOW-UP ACTIVITIES
This work has measured the levels of solids produced by representative regional facilities as settleable solids, total suspended solids, and dried solids. The more dramatic changes in water quality from aquaculture operations are associated with clean out events for removal of settled aquaculture waste materials. Solid wastes are most easily removed from culture systems by conventional water treatment processes, while nutrients, once they become dissolved, require treatment technologies that are cost prohibitive. Strategies to improve commercial fish foods from the perspective of waste management need to be evaluated. Better understanding of the influence of commercial diet formulations on the integrity of fecal solids and the consequent impact on nutrient release, holds promise of reducing the release of phosphorus into aquaculture effluents. This is one of the aspects of greatest regulatory concern due to its potential role in the eutrophication of receiving waters. The addition of fiber to the diet can potentially influence fecal durability in water and permit easier removal. The practicality of this strategy needs to be investigated and demonstrated.

In recirculating aquaculture systems the size distribution of suspended solids particles shifts to smaller sized particles that are the most difficult to remove, and more information is needed on the impact of such particulate solid matter on fish health and the performance of recirculating systems. Recycle systems also produce expectedly more concentrated waste, but they also permit more opportunities for innovative reuse or disposal. Efficient solids removal and management provides an avenue for the utilization of waste by-products as potentially beneficial resources in the context of integrated resource management plans.

Wise resource management calls for finding beneficial use for these concentrated aquaculture by-products. These types of practices can promote aquaculture as a beneficial or at least a benign influence on water resources when good stewardship is practiced. In this regard, comparison of real-life aquaculture production situations to other common land and water use practices will be helpful in arguing for realistic and just regulatory and permit situations. Comparing aquaculture waste production within the context of other contemporary land use practices with regard to impact on regional water quality, should be useful for demonstrating that current and prospective regional aquaculture is relatively benign environmentally.

Using the results of this project, a report needs to be prepared that contrasts the potential impact of regional aquaculture development with other contemporary agricultural, municipal, industrial, and natural resource land uses. There is a need for this information to be organized into an easily understood format so that normal aquaculture operating conditions can be viewed against the existing general background of water quality fluctuation and environmental impact. This report should also review and evaluate current research on alternative beneficial uses of aquaculture by-products, emphasizing integrated resource management and aimed at developing sustainable aquacultural practices. Options to be examined should include constructed wetlands, irrigation uses, hydroponics and even biogas production strategies. Often the situations and examples of such practices, as presented in the existing literature, deal with species, climates, and situations, which may or may not be applicable to the environmental and regulatory situations in our region. There is a need to review and present this information in relation to its relevance and application to aquaculture in the NCR.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1992-93	$77,064	$54,427	$15,000[a]			$69,427	$146,491
1993-94	$76,236	$43,261	$20,000[a]		$10,000[b]	$63,261	$139,497
TOTAL	$153,300	$97,688	$35,000		$10,000	$132,688	$285,988

[a]Glacial Springs Hatcheries
[b]Archer Daniels Midland

AQUACULTURE DRUGS (INADs/NADAs)

Progress Report for the Period
September 1, 1992 to August 31, 1995

NCRAC FUNDING LEVEL: $7,000 (September 1, 1993 to August 31, 1995)

PARTICIPANTS:

Ted R. Batterson	Michigan State University	Michigan
Henry S. Parker	USDA/CSREES/PAPPP	Washington, DC
Robert K. Ringer	Michigan State University	Michigan
Rosalie A. Schnick	Michigan State University	Wisconsin

PROJECT OBJECTIVES

(1) Ensure effective communications among groups involved with Investigational New Animal Drug/New Animal Drug Applications (INADs/NADAs), including liaison with Canada.

(2) Serve as an information conduit between INAD/NADA applicants and the U.S. Food and Drug Administration Center for Veterinary Medicine (CVM).

(3) Champion preparation and submission of INAD/NADA applications by affected groups.

(4) Seek opportunities for and encourage grouping of applications.

(5) Function as an information source for INAD/NADA applications.

(6) Coordinate educational efforts as appropriate.

(7) Identify potential funding sources for INAD/NADA activities.

ANTICIPATED BENEFITS

Investigation and approval of safe therapeutic drugs for use by the aquaculture industry is one of the highest priorities currently facing the industry. At present, only a few approved compounds are available to the industry and further development of the aquaculture industry is severely constrained by a lack of approved drugs essential for treating over 50 known aquaculture diseases. CVM has afforded the aquaculture industry throughout the U.S. with a "window of opportunity" to seek approval of legal drugs to be used in their production practices. The need for additional drugs is great, but securing data necessary to satisfy the requirements of CVM for drug approval is time consuming, costly, and procedures are rigorous. The obtaining of drugs for legal use through the INAD/NADA process is one method the industry can provide CVM with data on efficacy and also aid producers in their production practices.

Educational potential INAD/NADA applicants will save time and effort for both the industry and CVM. A National Coordinator for Aquaculture INAD/NADAs would serve as a conduit between an INAD/NADA applicant and the CVM. The Coordinator would help to alleviate time demands on CVM staff, thus allowing more time to process a greater number of applications as well as increasing the breadth of research endeavors within the industry.

The grouping of INAD applicants should help to alleviate redundancy, amalgamate efforts, and increase the amount of efficacy data, all of which should result in greater progress toward developing available, approved therapeutic drugs.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

In September 1992, Ringer, Professor Emeritus of Michigan State University, was hired on a part-time basis as National Coordinator for Aquaculture INAD Applications. He served in that capacity through August 31, 1994.

As National Coordinator for Aquaculture INADs Ringer participated with CVM in educational workshops on INAD procedures and requirements. These workshops were conducted throughout the U.S. This included workshops held in conjunction with the U.S. Trout Farmers Association, Boston Seafood Show, and Aquaculture Expo V in New Orleans. The workshop at the Boston Seafood Show was videotaped and is now available on cassette from the Northeastern Regional Aquaculture Center. In addition to the workshops, talks were presented on aquaculture drugs at the request of several organizations, including the World Aquaculture Society.

Ringer also helped in the preparation of a letter that CVM used in requesting disclosure information from those holding aquaculture INADs. By law, CVM cannot release any information about an INAD without such permission. A table containing information about these disclosures was made available to the general public. This included the names and addresses of the INAD holders as well as the drug and species of fish intended for use of the drug. It is intended that this table will be periodically updated after additional disclosure permissions have been obtained.

On May 15, 1995, Rosalie A. Schnick, recently retired Registration Officer from the National Biological Service's Upper Mississippi Science Center (UMSC), was hired on a three-quarter time basis as National Coordinator for Aquaculture New Animal Drug Applications (National NADA Coordinator).

As National NADA Coordinator, she organized and coordinated a major INAD/NADA workshop under sponsorship of CVM. The objectives of the workshop were to: (1) increase communications among coordinators, (2) develop working relationships, (3) review the roles and responsibilities of INAD\NADA coordinators, (4) coordinate the data generation for each drug, (5) consolidate INADs where possible, (6) determine the general format for INAD\NADA submissions and (7) exchange information on current progress and any significant research findings for each drug. Twenty-two INAD\NADA Coordinators and five CVM representatives participated in the workshop. The goals of the workshop were either met or plans were set in motion to accomplish the remainder.

Part of the coordination effort at the workshop centered on the new CVM policy, "CVM Aquaculture Workload Plan," distributed at the workshop. Because of limited resources, CVM will limit the compassionate INAD process to drugs identified and prioritized by the Joint Subcommittee on Aquaculture (JSA) Working Group on Quality Assurance in Aquaculture Production (Working Group). The National NADA Coordinator was requested to survey the aquaculture industry (public and private) to develop such a list recognized by the JSA. She sent out mailings on August 14 and September 20, 1995 and requested a final review by the Working Group on November 9, 1995 that was due by November 22, 1995. CVM will deny a compassionate unless the sponsor of the INAD is part of a collaborative effort to generate all of the data necessary for an approval and/or has a commitment from a pharmaceutical manufacturer to sponsor an NADA of the product of a JSA prioritized drug.

Schnick worked with CVM, Auburn University, and tilapia producers to develop an INAD on methyltestosterone (MT) for tilapia and then worked to allow the use of MT on yellow perch under the Auburn INAD. In November 1995, CVM determined that feed manufacturers of MT could become sponsors of a NADA. The National NADA Coordinator sent out 29 letters to prospective NADA sponsors and has received two positive responses.

Schnick worked with AquaFuture, Inc. to gain a sponsor for both amoxicillin and erythromycin and that sponsor is Vetrepharm Limited (United Kingdom). She contacted all the holders of disclosed INADs on human chorionic gonadotropin (hCG) at the urging of CVM to send all the data to the sponsor, Intervet, Inc. to be incorporated in a forthcoming submission to CVM by Intervet.

Progress has been made on interactions with current or potential sponsors of NADAs for chloramine-T and hydrogen peroxide and letters will soon go out to potential sponsors of benzocaine. The National NADA Coordinator sent letters to all holders of both disclosed and undisclosed (through CVM) INADs of chloramine-T informing them that an effort would be made to consolidate and coordinate these INADS, develop label claims, and identify pivotal study sites at an upcoming meeting on INAD\NADAs in Council Bluffs, Iowa, on February 6-8, 1996. A NADA submission was made by UMSC to CVM on December 15, 1995 of a report on the safety of formalin on fish eggs. This submission will be reviewed by CVM along with the data on the use of formalin as a parasiticide on hybrid striped bass developed at Auburn University. These submissions will hopefully lead to the extension of the formalin NADA to additional species and, thus, remove the need for INADs on formalin.

Schnick interacted with Rob Armstrong, Canadian Coordinator for Aquaculture Drug Approvals, on several occasions to coordinate activities between the United States and Canada.

Schnick worked hard to maintain federal funding for the federal-state aquaculture drug partnership that includes research on eight high priority drugs and the crop grouping concept.

WORK PLANNED

The National NADA Coordinator developed an action plan when she began the position that centers on coordinating all drugs of high priority for aquaculture toward NADAs through the INAD process.

It is anticipated that several INAD/NADA meetings in February 1996 will result in further coordination and consolidation of INAD\NADAs. A major effort will be made to develop an action plan for a INAD/NADA on amoxicillin involving researchers and producers.

Efforts will be made to identify and secure funds for the continued financial support for the position of National NADA coordinator at a minimum of a half-time level of activity, but ideally for full-time.

IMPACTS

Establishment of the National NADA Coordinator has resulted in coordination, consolidation, and increased involvement in the INAD/NADA process on aquaculture drugs. Several new sponsors of NADAs have been identified and progress has been made toward unified efforts on these new INAD/NADAs.

This enhanced coordination will help gain extensions and expansions of approved NADAs and gain approvals for new NADAs.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED

See Appendix.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1992-93				$17,000[a]		$17,000	$17,000
1993-94	$2,000			$12,180[b]	$4,000[c]	$16,180	$18,180
1994-95	$5,000		$23,750[d]	$70,000[e]	$10,000[f]	$103,750	$108,750
TOTAL	$7,000		$23,750	$99,180	$14,000	$136,930	$143,930

[a]USDA funding through a Cooperative Agreement with NCRAC

[b]USDA funding through a Cooperative Agreement with NCRAC ($8,500) and FDA's Office of Seafood Safety ($3,680)

[c]Northeastern Regional Aquaculture Center ($2,000) and Southern Regional Aquaculture Center ($2,000)

[d]American Pet Products Manufacturers Association ($7,500), American Veterinary Medical Association ($10,000), Catfish Farmers of America ($2,000), Fish Health Section of AFS ($1,000), Florida Tropical Fish Farm Association, Inc. ($500), Natchez Anima Supply ($1,000), National Aquaculture Council ($1,000), and Striped Bass and Hybrid Producers Association ($250)

[e]USDA funding through a Cooperative Agreement with NCRAC ($23,000), CVM ($22,000), and USDI/NBS International Association of Fish and Wildlife Agencies Project ($25,000)

[f]Northeastern Regional Aquaculture Center ($5,000) and Tropical and Subtropical Regional Aquaculture Center ($5,000)

APPENDIX

EXTENSION

NCRAC Extension Fact Sheet Series

Garling, D.L. 1992. Making plans for commercial aquaculture in the North Central Region. NCRAC Fact Sheet Series #101, NCRAC Publications Office, Iowa State University, Ames.

Harding, L.M., C.P. Clouse, R.C. Summerfelt, and J.E. Morris. 1992. Pond culture of walleye fingerlings. NCRAC Fact Sheet Series #102, NCRAC Publications Office, Iowa State University, Ames.

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Thomas, S.K., R.M. Sullivan, R.L Vertrees, and D.W. Floyd. 1992. Aquaculture law in the north central states: a digest of state statutes pertaining to the production and marketing of aquacultural products. NCRAC Technical Bulletin Series #101, NCRAC Publications Office, Iowa State University, Ames.

Swann, L. 1992. A basic overview of aquaculture: history, water quality, types of aquaculture, production methods. NCRAC Technical Bulletin Series #102, NCRAC Publications Office, Iowa State University, Ames.

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Lichtkoppler, F.P. 1993. Factors to consider in establishing a successful aquaculture business in the North Central Region. NCRAC Technical Bulletin Series #106, NCRAC Publications Office, Iowa State University, Ames.

Swann, L., and J.R. Riepe. 1994. Niche marketing your aquaculture products. NCRAC Technical Bulletin Series #107, NCRAC Publications Office, Iowa State University, Ames.

NCRAC Video Series

Swann, L. 1992. Something fishy: hybrid striped bass in cages. VHS format, 12 min. NCRAC Video Series #101, NCRAC Publications Office, Iowa State University, Ames.

Swann, L., editor. 1993. Investing in freshwater aquaculture. VHS format, 120 min. NCRAC Video Series #103, NCRAC Publications Office, Iowa State University, Ames.

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Other Videos

Kayes, T.B., and K. Mathiesen, editors. 1994. Investing in freshwater aquaculture: a reprise (part I). VHS format, 38 min. Cooperative Extension, Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln.

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Hushak, L.J. 1993. North Central Regional aquaculture industry situation and outlook report, volume 1 (revised October 1993). NCRAC Publications Office, Iowa State University, Ames.

Workshops and Conferences

Salmonid Culture, East Lansing, Michigan, March 23-24, 1990. (Donald L. Garling)

Midwest Regional Cage Fish Culture Workshop, Jasper, Indiana, August 24-25, 1990. (LaDon Swann)

Aquaculture Leader Training for Great Lakes Sea Grant Extension Agents, Manitowoc, Wisconsin, October 23, 1990. (David J. Landkamer and LaDon Swann)

Regional Workshop of Commercial Fish Culture Using Water Reuse Systems, Normal, Illinois, November 2-3, 1990. (LaDon Swann)

North Central Aquaculture Conference, Kalamazoo, Michigan, March 18-21, 1991. (Donald L. Garling, Lead; David J. Landkamer, Joseph E. Morris and Ronald Kinnunen, Steering Committee)

Crayfish Symposium, Carbondale, Illinois, March 23-24, 1991. (Daniel A. Selock and Christopher C. Kohler)

Fish Transportation Workshops, Marion, Illinois, April 6, 1991 and West Lafayette, Indiana, April 20, 1991. (LaDon Swann and Daniel A. Selock)

Regional Workshop on Commercial Fish Culture Using Water Recirculating Systems, Normal, Illinois, November 15-16, 1991. (LaDon Swann)

National Aquaculture Extension Workshop, Ferndale, Arkansas, March 3-7, 1992. (Joseph E. Morris, Steering Committee)

Regional Workshop on Commercial Fish Culture Using Water Recirculating Systems, Normal, Illinois, November 19-20, 1992. (LaDon Swann)

In-Service Training for CES and Sea Grant Personnel, Gretna, Nebraska, February 9, 1993. (Terrence B. Kayes and Joseph E. Morris)

Aquaculture Leader Training, Alexandria, Minnesota, March 6, 1993. (Jeffrey L. Gunderson and Joseph E. Morris)

Investing in Freshwater Aquaculture, Satellite Videoconference, Purdue University, April 10, 1993 (LaDon Swann)

National Extension Wildlife and Fisheries Workshop, Kansas City, Missouri, April 29-May 2, 1993. (Joseph E. Morris)

Commercial Aquaculture Recirculation Systems, Piketon, Ohio, July 10, 1993. (James E. Ebeling)

Yellow Perch and Hybrid Striped Bass Aquaculture Workshop, Piketon, Ohio, July 9, 1994. (James E. Ebeling and Christopher C. Kohler)

Workshop on Getting Started in Commercial Aquaculture Raising Crayfish and Yellow Perch, Jasper, Indiana, October 14-15, 1994. (LaDon Swann)

North Central Aquaculture Conference, Minneapolis, Minnesota, February 17-18, 1995. (Jeffrey L. Gunderson, Lead; Fred P. Binkowski, Donald L. Garling, Terrence B. Kayes, Ronald E. Kinnunen, Joseph E. Morris, and LaDon Swann, Steering Committee)

Walleye Culture Workshop, Minneapolis, Minnesota, February 17-18, 1995. (Jeffrey L. Gunderson)

Yellow Perch Aquaculture Workshop, Spring Lake, Michigan, June 15-16, 1995. (Donald L. Garling)

Rainbow Trout Production: Indoors/Outdoors, Piketon, Ohio, July 8, 1995. (James E. Ebeling)

Hybrid Striped Bass Workshop, Champaign-Urbana, Illinois, November 4, 1995. (Christoper C. Kohler, LaDon Swann, and Joseph E. Morris)

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Brown, G.J., and L.J. Hushak. 1991. The

NCRAC producers survey and what we have learned: an interim report. Pages 69-71 *in* Proceedings of the North Central Aquaculture Conference, Kalamazoo, Michigan, March 18-21, 1991.

Edon, A.M.T. 1994. Economic analysis of an intensive recirculating system for the production of advanced walleye fingerlings in the north central region. Master’s thesis. Illinois State University, Normal.

Floyd, D.W., and R.M. Sullivan. 1990. Natural resources and aquaculture: the policy environment in the North Central states. Proceedings of the Third Symposium on Social Science and Resource Management, Texas A&M University, College Station, Texas.

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